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FORPLAN: An Evaluation of a Forest Planning Tool

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Preface

The National Forest Management Act of 1976 requires comprehensive multi-resource plans for each national forest administered by the Forest Service. The planning process detailed in the Section 6 of the Act and the Section 6 Regulations which expand and interpret the planning and management requirements of the Act have resulted in the largest and most complicated planning analysis ever attempted by a natural resource agency. Much of this planning activity has focused on the mathematical programming procedure FORPLAN which was selected as the "tool" to support national forest planning. In the past 7 years, the Forest Service has dedicated a considerable amount of energy to completing FORPLAN analyses, and final forest plans are now beginning to emerge. As plans have been completed, client groups have directed substantial criticism at specific alternatives contained in the plans; but they have also extended their criticism to the FORPLAN process and its results. Criticisms of FORPLAN include: (1) the complexity of the process and results included in the plans mean that the logic supporting proposals can not be understood by client groups, (2) the FORPLAN model is inappropriate for many planning situations on national forests because of its emphasis on timber management, (3) the model is so complex that national forest specialists have difficulty implementing it correctly, and (4) that the models can be structured to produce plans that fit preconceived notions of "best" plans, thus, precluding balanced consideration of reasonable and perhaps preferred alternatives. Other criticisms have been made, but these serve to illustrate the controversy that has arisen around the FORPLAN model and process.

The Forest Service, Colorado State University, and Washington State University with the co-sponsorship of the American Forestry Association, organized the symposium for two reasons. The need for evaluations of FORPLAN by non-Forest Service experts was a major rationale for conducting the symposium, and the second and equally important reason was to provide an opportunity for Forest Service client groups and other interested people to participate in a review of FORPLAN.

Initially the symposium was structured to focus on the FORPLAN model, but the fact that the model is so tightly knit into the Forest Service's planning process resulted in the planning process itself being discussed as much or more than the model itself. This was reflected in every paper given at the symposium and in the discussions that followed presentation of the papers. The symposium was organized into three separate sessions which included presentation of papers by their authors, formal discussions of the papers, and open discussion with the symposium participants.

The first session was primarily dedicated to presentations by Forest Service personnel that described Forest Service development and use of FORPLAN. The objective of this session was to present an organized statement by the Forest Service. These papers covered: (1) the criteria used to select and implement FORPLAN, (2) the evolution of FORPLAN, (3) the operations research structure of FORPLAN, and (4) Forest Service experiences in using FORPLAN. In addition to the Forest Service presentations, the first session included papers by Dr. Dennis Teeguarden, who served as a member of the Committee of Scientists, and Dr. Norman Johnson, the principal architect of FORPLAN. This first session was a synopsis of an earlier Forest Service Workshop: Lessons from Using FORPLAN (USDA 1986).

The second session focused on experiences of state, province, private, and university organizations with FORPLAN. There were presentations by experts from California, British Columbia, Boise Cascade, and North Carolina State University.

Separate formal presentations evaluating FORPLAN from economic, ecological, and operations research perspectives were made in session three. These papers and the related presentations by discussions constituted the major evaluative phase of the symposium. Effective evaluation was facilitated through Forest Service and non-agency joint authorship. Charles Wilkinson's paper on the legal and political context of public land planning and management took a calculated look into the future during the banquet part of this session.

Dr. Roger Sedjo of Resources for the Future, and Dr. John Sessions of Oregon State University closed the symposium with summaries.

Rapid publication of these proceedings was made possible largely because most of the authors prepared their manuscripts on the Forest Service Data General system or other word processing equipment, and then submitted them electronically or on magnetic diskette. The manuscripts then were processed through computer-based usage and spelling checkers, and were put into camera-ready format. Because the papers are being printed with the content essentially as received, the authors are responsible for the accuracy of their papers; opinions expressed by the authors may not necessarily reflect the policy of the Forest Service or the U.S. Department of Agriculture.

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FORPLAN:
An Evaluation of a Forest Planning Tool

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Session I:

Development and Implementation of FORPLAN by the Forest Service.

Characterizations of the FORPLAN Analysis System

Thomas R. Mitchell and Brian M. Kent[1]

Abstract.--This paper provides an overview of a linear programming based system (FORPLAN) which is the principal analysis tool for land management planning on national forests. Topics discussed include how FORPLAN is used, the evolution and nature of the system, and the types of data input that are required.

Forest planning, as it is now carried out by the USDA Forest Service under the National Forest Management Act (NFMA), is a complex task that requires many varied analyses. These include an analysis of the capabilities of a National Forest (hereafter, forest) to produce goods and services; an analysis of issues, concerns, and opportunities facing management of a forest; analysis of social impacts; analysis of economic impacts; analysis of demands for goods and services; and analysis of cost efficiency. Central among these analyses is sorting through possible management options to identify the mix and timing of options that will yield the maximum net public benefit from management of the forest as a whole.

FORPLAN is a software package designed to aid this sorting and provide information regarding the combined effects of various mixes of management options. As such, FORPLAN is the central analysis tool used in forest planning. This paper discusses input to FORPLAN, reports that can be generated from FORPLAN, the differences between versions of FORPLAN, and how FORPLAN is used to accomplish required analyses.

In the discussion that follows, it is assumed that the reader has little or no background in forest planning, FORPLAN, or linear programming. Because a single paper cannot do justice to all these topics, every effort will be made to point the reader to other publications that can help increase understanding.

The Problem and One Method of Addressing It

A forest is managed by applying specific practices to specific areas on that forest. These practices are applied to help produce goods and services from a forest and to maintain the productivity of the forest. The practices applied, where they are applied, when they are applied, the sequence in which they are applied, and the standards under which they are applied all effect the amount, quality, and flow of goods and services. Also, the practices that are carried out determine, in large part, the costs of management of the forest. Briefly, then, the problem faced in forest planning is the choice of which practices are to be applied in what sequence to each area of the forest in order to produce the mix and flow of goods and services that will maximize net public benefit.

One way to address this problem is to subdivide a forest into distinct units. These distinct units are termed "Analysis Areas" (AAs). Resource data for each AA can be compiled to identify its capabilities for producing mixes of goods and services. Also, the feasibility of applying various practices and the probable effects of each practice on the production of goods and services from each AA can be assessed.

Based on such information, individual management practices can be grouped into sets that, when applied to a particular AA, will result in the achievement of specific objectives. These sets of practices, along with the standards governing how they are applied, represent the management options. Each set is referred to as a prescription (Rx). Each prescription is designed to achieve a specific management intent and produce a multiple-use mix of goods and services on a specific analysis area. A full range of prescriptions can be developed for each AA representing various possible management intents and mixes of goods and services.

Once a set of prescriptions has been developed for a specific analysis area, the results of applying each prescription can be displayed as shown in table 1. Because of the time span involved in management of a forest, this display can include several time periods (usually a decade in length) representing the sequence of practices and effects through time.

Numbers in table 1 represent what would happen if 1 acre of analysis area 135 were managed under each of the six choices or prescriptions. The prescriptions represent no harvest of timber (Rx 1351), shelterwood harvest (Rx 1352, 1353, 1354), or clearcutting of timber (Rx 1355 and 1356) at various times. As an example that may further clarify this table, the difference between Rx's 1355 and 1356 is that in the former, the acre would be clearcut in decade 3, while in the latter, it would be clearcut in decade 4. (If timing is the only difference between these two columns, then they represent different timing options or choices for a single Rx rather than different Rxs.)

A similar table could be developed for each analysis area. Further, these tables could be combined to create one

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Table 1.--Some implications in terms of costs and output levels for six prescriptions applied to analysis area 135.

Practices, costs & output levels of goods and services	Prescriptions for AA 135 1351	1352	1353	1354	1355	1356
Timber sale preparation decade 1	0	35	0	0	0	0
Timber sale preparation decade 2	0	0	35	0	30	0
Timber sale preparation decade 3	0	0	0	35	0	30

MCF timber decade 1	0	0	0	0	0	0
MCF timber decade 2	0	1.7	0	0	0	0
MCF timber decade 3	0	1.0	1.9	0	2.4	0
MCF timber decade 4	0	0	1.1	2.1	0	2.5
MCF timber decade 5	0	0	0	0.9	0	0

Preservation Visuals 1	1.0	1.0	1.0	1.0	1.0	1.0
Preservation Visuals 2	1.0	0	1.0	1.0	1.0	1.0
Preservation Visuals 3	1.0	0	0	1.0	0	1.0
Preservation Visuals 4	1.0	0	0	0	0	0

Wildlife forage decade 1	0	0	0	0	0	0
Wildlife forage decade 2	0	250	0	0	0	0
Wildlife forage decade 3	0	200	250	0	350	0

large matrix representing all prescriptions for all analysis areas on a Forest. This matrix, then, would be a display of all the possible management prescriptions for each analysis area, the costs of each of these prescriptions and the resulting quantity, quality and flow of goods and services.

At this point it would be possible to sort through this matrix to identify which prescriptions should be applied to each analysis area to produce a desired flow of goods and services through time from the forest. Because cost and benefit information is included in such a matrix, the set of prescriptions to be applied that will produce a desired mix of goods and services while maximizing cost efficiency could be identified.

This is not an easy task to do by hand. The number of analysis areas for a forest can range from 100 to 400 or more. The number of time periods considered must be at least 5 decades for all goods and services and for timber harvest scheduling questions at least 15 decades are usually considered. This means that such a matrix could grow to be 1,000 to 5,000 rows by 20,000 to 125,000 columns. A matrix of this size results in many numbers and choices to sort through to find the appropriate mix of prescriptions. The problem becomes even more complex when constraints representing production targets, policy limitations, etc. are added to the matrix. An automated procedure of some type would be very helpful here.

One such procedure is an operations research technique called "linear programming." Briefly, linear programming (LP) will sort through a mix of choices such as those represented in table 1 and identify the ones that will meet a set of objectives (desired mix of goods and services) while maximizing or minimizing a specific measure such as present net value.

From a simplistic viewpoint, an LP model consists of three components:[2]

1. A set of decision variables,

2. A set of constraints,

3. An objective function or criterion of optimality.

In a forest planning application, the decision variables or columns in the matrix represent timing choices for prescriptions for each AA. Constraints are rows in the matrix and represent: physical resource availability (i.e., the amount of land within each analysis area); production targets (i.e., produce so many recreation visitor days in a given decade); or restrictions (i.e., budget constraints).

An analysis task, then, is to translate information representing analysis areas and management prescriptions as shown in table 1 into the format of an LP problem. Once formulated, this problem is solved using a computer based LP solution package. The solution consists of the set of prescription timing choices that results in the largest (or smallest) possible value of the objective function subject to the limits imposed by all the constraints. Said another way, the solution shows the number of acres on each analysis area that should be managed by (or allocated to) each prescription timing choice (Kent 1980).

FORPLAN: An Overview of the System

It is possible to build an LP model (even a large one) by hand. However, early on in the process of developing forest

[2]Except for this brief description, LP is not be discussed in detail here. It was developed in the 1940s (Dantzig 1963). For more details, refer to any introductory text on operations research (c.f. Hillier and Lieberman 1974), or to the LP manual by Kent (1980), or the paper by Bare and Field in these proceedings.

plans it became obvious to Forest Service personnel that the development of some sort of automated procedure for doing so was almost a necessity. Two reasons for this are:

1. The skill level required to construct a large LP model by hand is considerable and persons having such skills would have to have been available on every forest.

2. The development of a standardized modeling approach, while difficult under any circumstance, would have been even more so if each forest staff developed their own approach to forest planning analysis.

As a result, a LP based system known as FORPLAN was chosen to be the principal tool for Forest planning analysis.[3] FORPLAN analysis involves three stages for the formulation and solution of an LP problem as shown in figure 1. Two of these directly involve FORPLAN; the other involves the use of the computerized LP solution procedure.

The first stage directly involves FORPLAN in building a linear programming matrix. Before FORPLAN is used, each forest needs to delineate analysis areas, develop management prescriptions for each and estimate costs, outputs, effects and benefits for each combination of prescription and analysis area. This is then coded for input into FORPLAN. After the user has prepared the FORPLAN input data (no small task), the FORPLAN matrix generator is used to edit this data for errors. Once any errors have been corrected, the matrix generator can be used to create the LP model data.

The second stage involves solving the LP problem. The matrix generated by FORPLAN in the first stage is used by the LP solution system (here, the Sperry Corporation proprietary system FMPS) to solve the resultant LP model.[4] Once this solution has been obtained, the second stage has been completed. Note that this stage does not directly involve FORPLAN.

Information about the optimal solution, as displayed by FMPS, is not readily understandable to people other than those trained in Operations Research techniques. Therefore, the third stage is necessary to interpret the implications of the solution in terms that are meaningful to an interdisciplinary team, the public, and decision makers. This task is accomplished by the FORPLAN report writer. The report writer uses the same input data as does the matrix generator, in addition to the optimal solution results. Its output is in the form of tables or graphs.

In short, a Forest uses FORPLAN to: (1) build a linear programming matrix representing management prescriptions designed to solve problems facing the Forest and to report the results of the optimal solution of this LP. Along the way, the FMPS system is used to solve the LP problem that FORPLAN generates.

[3]For more details on how this came about, refer to Russell (1986) and Jones (1986a). Most of the development work on this system had, at that time, been done by Dr. K. N. Johnson, now of Oregon State University, and it evolved from two earlier LP systems, Timber RAM (Navon 1971) and MUSYC (Johnson and Jones 1979), that had been used by the Forest Service.

[4]The use of the FMPS system in the solution of FORPLAN models is interesting. More details on this can be found in the paper by Kent, Kelly, and Flowers (1980).

Evolution of the FORPLAN System

FORPLAN was first made available for use by forests in 1980. As a result of lessons learned over the next 2 years, a second version[5] called Version 2 of FORPLAN was developed. (Details on some of the differences between the two versions will be presented later in this paper.) Again, as with Version 1, much of the development work was done by K. N. Johnson in close cooperation with Forest Service personnel.[6] After Johnson initially developed each version, the Forest Service took over maintenance, user support, and development activities.[7]

FORPLAN, as developed and supported in the Forest Service, is not a single software package that was developed once and held static. Rather, each version has gone through several needed changes as experience was gained in their use. To accommodate changing and upgrading FORPLAN, a system of releases within each version was used. Briefly, releases are modifications of a version of FORPLAN done to correct errors and to add needed features as identified by the user community. Each release is documented as to its input requirements and new features. Further, as new releases are issued, users are encouraged to change from one release to the next. Releases may be issued after a forest is already well into analysis, so switching may not be practical. Therefore, all releases being used by Forests are maintained and actively supported. Version 1 has 14 releases and Version 2 has 12 releases. About two-thirds of the forests used Version 1 for their planning analyses with the balance using Version 2.

FORPLAN Documentation

Over the past 3 years, a series of documents have been developed for each version. All but two of these are available from the LMP Systems Section in Fort Collins. The Overviews for each version have already been mentioned. For Version 1 there also is a Mathematical Programmer's Guide (MPG) (Kent, Kelly, and King 1985), a User's Guide (Kelly, Kent, Johnson, Jones 1986), and a Structures and Options Guide (Johnson and Crim 1986).

[5]At this point, the original version became known as Version 1 of FORPLAN and is referred to by that name for the balance of this paper. The term FORPLAN without a version qualifier is used when both versions are being referred to.

[6]There are several references that provide additional details on this evolution. Detailed discussions can be found in the Version 1 Overview (Johnson 1986) and the Version 2 Overview (Johnson, Stuart, and Crim 1986). Iverson and Alston (1986) trace this evolution from a somewhat different viewpoint. Finally, the papers by Jones (1986b) and Weisz (1986) presented earlier in this symposium provide additional information.

[7]User support has been available both from Regional Offices and from the LMP Systems Section (Washington Office) in Fort Collins, Colorado. The Systems Section did the maintenance and development work. Training has been provided both by Regional Offices and the Systems Section.

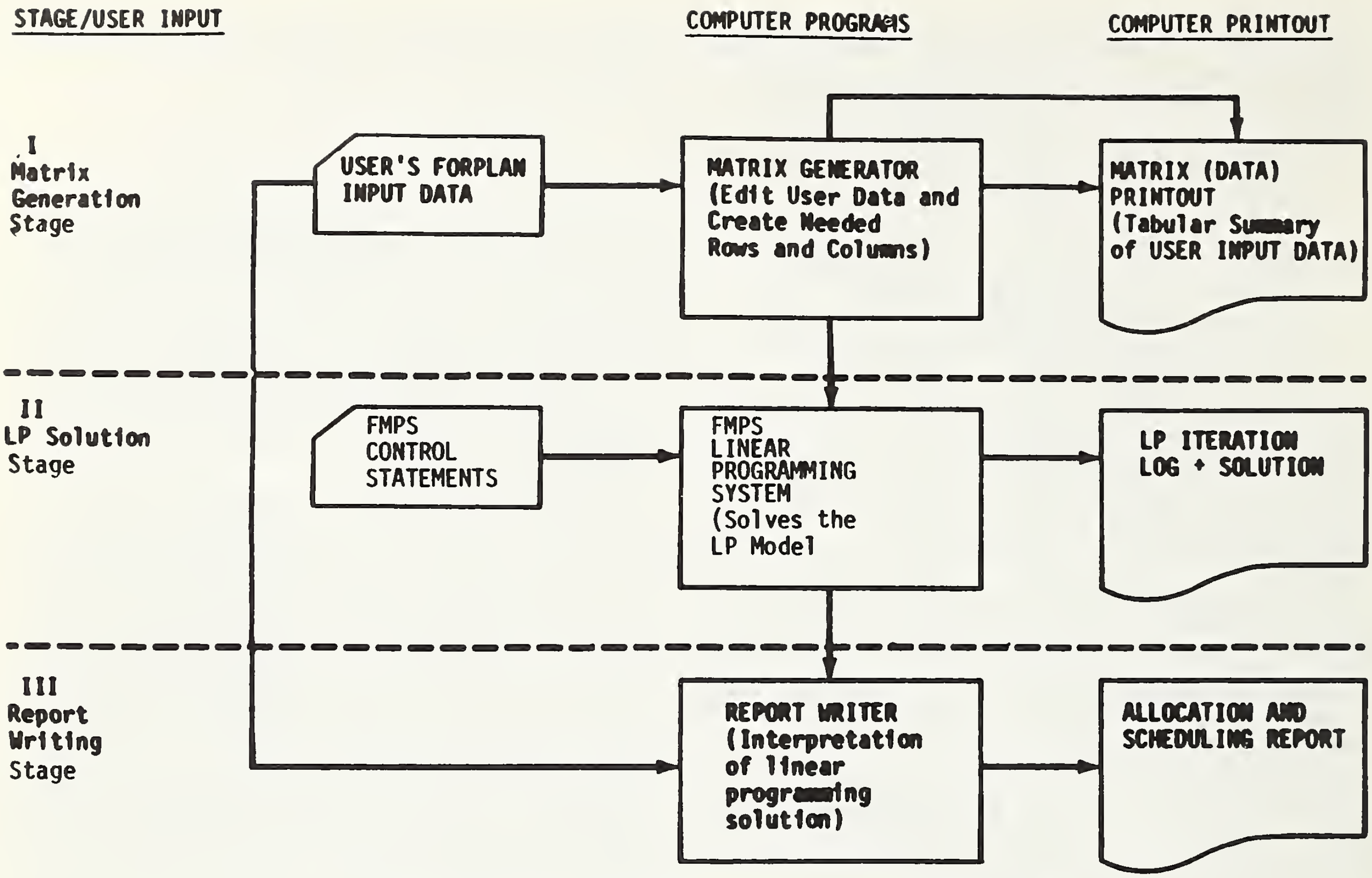

Figure 1.--System structure of FORPLAN (FORest PLANning model).

The MPG describes the mathematical relationships (constraints, objective functions, decision variables, etc.) that may be generated using Version 1. This document also contains some simple examples that are intended to show interrelationships between such things as analysis areas, prescriptions, etc. The User's Guide describes data input conventions and capabilities associated with the matrix generator. The Structures and Options Guide provides additional information on capabilities that the user can avail him or herself of. It also gives examples of the different LP model formulations or structures that Version 1 can provide.

The other documents that are available at this writing for Version 2 include a User's Guide (Gilbert et al. 1986), and an Operations Manual (Robinson, Kelly, and Bevers 1986). The User's Guide fulfills the same function for Version 2 as the Version 1 User's Guide does for Version 1. The Operations Manual describes how the Version 2 system interfaces with FMPS and with the Sperry Univac computer operating system.

Two additional Version 2 documents are in progress, an MPG (Johnson and Stuart, in press) and an Options Guide (Johnson, Crim, Stuart, and Kent, in press). These documents will also provide the same types of information as their Version 1 counterparts. The only difference is that the LP model formulations or structures are contained in the MPG.

The FORPLAN System vs. FORPLAN Models

Regardless of the version chosen, each forest is responsible for identifying how FORPLAN will be used to accomplish required analysis within the direction provided in the NFMA planning regulations (36 CFR 219) and within direction provided by the Chief's office and Regional offices. This includes identifying and structuring input to FORPLAN as well as identifying which version and features of FORPLAN that will be used.

These facts result in the development of a wide range of different FORPLAN models, because the forests vary considerably and the range of planning problems that must be addressed, varies considerably from forest to forest. Different forests will use different mixes of constraints, different features associated with the input data to the matrix generator, and different LP model formulations, depending on the nature of the problems they are trying to solve. In other words, while there are two FORPLAN versions, there are at least as many different FORPLAN models as there are forests.

Data Input to FORPLAN

As the previous discussion implies, the user has a range of options about what types of data and how much of any type (i.e., number of analysis areas, prescriptions, etc.) to provide as input to FORPLAN. However, there are certain

general categories of information that are included in all FORPLAN models. These include:

1. Information regarding analysis areas. Each interdisciplinary team is responsible for subdividing their Forest into analysis areas and including these as input to FORPLAN.

2. Information regarding prescriptions for each analysis area. Again each forest is responsible for developing prescriptions for each analysis area. These are tailored on a forest by forest basis based on the particular problems to be addressed in forest Planning, characteristics of analysis areas used on each forest, and the range of practices and uses that can be applied and managed for on each analysis area.

3. Cost information is included for each practice included in each prescription. Also included are differences in costs of practices based both on analysis area characteristics and on differing standards for prescriptions.

4. "Yield Tables" containing estimates of production levels of goods and services that would result from application of prescriptions to analysis areas under the standards included for each prescription.

5. Benefit information representing both the direct dollar return from priced goods and services such as timber and forage for domestic livestock and estimates of dollar benefit values for goods and services for which there is no established market value such as dispersed recreation use.

6. Objective functions[8] and constraints. An objective function, as mentioned above, is the criterion of optimality to be used in determining the optimal solution. Examples include the maximization of present net value over the planning horizon, or the maximization of a good or service such as the production of elk winter range for 5 decades or the timber volume harvested in the first period. Constraints are used to impose targets on the production of goods and services. For example, forage for domestic livestock should be greater or equal to 90,000 AUMs in the first decade, timber harvest should be greater or equal to 40 MMBF in the first decade and the number of semi-primitive non-motorized recreation visitor days produced should be greater or equal to 400,000 RVDs in the first decade. Because of the way linear programming problems are structured, these desired levels are termed "right-hand-side values."

7. Report Selection Parameters. Both versions allow the user the choice of selecting which reports the report writer should print for a given run. These parameters are used to control this selection.

Following are more detailed discussions of some of the items just listed. Attempts will be made in these discussions to identify some of the differences between the two versions of FORPLAN.

Analysis Areas

Two types of analysis areas are typically used in FORPLAN. The first is termed a "homogeneous - noncontiguous" analysis area. Delineation of these analysis areas is based on the grouping together of similar land types, cover types, and timber age classes (e.g., a single AA on a forest could be all lands that have lodgepole pine *(Pinus contorta)* cover 100 to 120 years old, with moderate site productivity on stable soils and where natural regeneration is possible when clear cutting is used). Delineating and mapping this type of analysis area is easy based on the typical kinds of information available on a forest. Furthermore, development of prescriptions and estimating yields, costs, and benefits is straightforward because it is assumed that each acre of an analysis area will have the same response to practices. This type of analysis area is similar to area definitions used in Timber RAM and MUSYC and can be used in both Version 1 and Version 2.

The second type of analysis area is termed a "heterogeneous - contiguous" analysis area. These represent distinct and definable geographic areas such as watersheds or range allotments. With this type of analysis area, such things as range management, vegetative diversity, and the production of goods and services which rely on the spatial arrangement of different types and conditions of cover are easier to represent in an LP model than they are with the homogeneous - noncontiguous analysis areas. Furthermore, representing such things as costs, output levels of goods and services and probable use of a specific area on the Forest is easier. However, use of this type of analysis area means that development of prescriptions and timing options is not as straight forward or as easy to accomplish. Realistically, this type of analysis area can only be used in Version 2, and the need to use such an analysis area to address specific problems was one of the primary motivations behind the development of this version.

In Version 1, the types of information used to characterize analysis areas is fixed. It consists of a set of "identifiers" or names for the strata that are used to delineate analysis area boundaries, an initial age for each analysis area, and the area of the analysis area. For more details on this, refer to Section 5 of the Version 1 User's Guide (Kelly et al. 1986) or to Section 1.4 of the Version 1 MPG (Kent et al. 1985).

In Version 2, the user can characterize analysis areas in the same manner as in Version 1 except that age is not specified. However, to provide as much generality as possible, the user does not have to specify any characteristics of an analysis area other than its size. Any combination in between also is possible. For more details,

[8]Version 1 can generate only a single objective function in any given matrix generation, while in Version 2, up to five objective functions may be generated (of course only one can be optimized at a time regardless of version).

refer to Sections 5 and 9 of the Version 2 User's Guide (Gilbert et al. 1982).

Prescriptions

A prescription is a specific set of practices to be applied at a specified time and in a specified sequence to an analysis area using a specified set of standards. In Version 1, prescriptions fall into one of two[9] categories, prescriptions that involve the harvest of timber and those that don't. For more details on this, see Section 6 of the Version 1 User's Guide (Kelly et al. 1986) or Section 1.4 of the Version 1 MPG (Kent et al. 1985). Briefly, prescriptions in this version are characterized, in part, by the following user input data:

Data Item	Brief Description
1. prescription number	a label for the prescription
2. analysis area number	identify the analysis area to which it applies
3. management emphasis	the management philosophy for the prescription
4. management intensity	the level of investment for the prescription
5. table numbers for economic and yield tables	pointers to tell the FORPLAN programs where to get economic and yield information for the prescription
6. information on timing choices to be generated	determines which timing choices for implementation, thinning, and harvesting the matrix generator will consider for the prescription

This information is used by the matrix generator to develop the decision variables (columns) for each of the timing choices for each of the prescriptions the user specifies.

Early on in the use of Version 1, it became obvious that this structure for representing prescription data had two major deficiencies.

1. There was too much of a "block box" aura concerning how the matrix generator used information on yields, economics, timing choices, etc. to represent prescriptions in a FORPLAN model.

2. Data input was tedious and lengthy because all information had to be entered for each prescription no matter how repetitive it might be.

Attempts were made to address both of these problems in designing Version 2. A new approach for representing prescriptions, known as directly entered (DE) prescriptions was incorporated. In this approach, rather than relying on the matrix generator to use yield, cost and benefit tables to build prescription timing choices, the user must enter all such information column by column for each prescription timing choice to be represented in the model. This solves the "block box" problem because every implication of every prescription is explicitly entered by the user.

This type of prescription was primarily developed for and used with the heterogeneous - contiguous analysis areas. Use of this type of analysis area and a DE prescription allows an interdisciplinary team to design development and management of a specific geographic area on a Forest, and record all the practices, costs, output levels, and benefits that would occur under the resultant prescription. While the DE feature provides an almost unlimited capability to tailor management options for specific locations, it also requires much time and work. There are two disadvantages.

1. Analysis of timber harvest scheduling problems requires that many timing options be considered - from a practical standpoint this can become almost impossible using only DE prescriptions.

2. The amount of input necessary for directly entering prescriptions can be large (considerably larger than in Version 1) and thereby make checking for coding and keypunching errors very difficult and time consuming.

As is evidenced by the previous sentence, while DE prescriptions resolved much of the "black box" problem, they did nothing to improve the ease of data input. To resolve this second problem, which stems from a requirement to repeatedly enter a piece of data every time it is used, an option called "theming" was incorporated in Version 2. This option allows the user to "theme" repetitive information associated with prescriptions to one or more general characteristics associated with a group of prescriptions. These characteristics typically relate both to the prescriptions and to the analysis areas to which they apply.

For example, one analysis area could contain lodgepole pine 100 to 120 years old, while another could be exactly the same except that the age of the timber was 80 to 100 years. The basic prescriptions for each could be the same. The only difference would be a reflection of the age differences in terms of yields, etc. In Version 1 or in DE prescriptions in Version 2, all information about identical prescriptions would need to be repeated for each analysis area. As an alternative in Version 2, identical information could be "themed" to both analysis areas, keying off the common property that they are stands of lodgepole pine. It then would only have to be entered one time in the data set. More information on both DE prescriptions and theming can be found in the Version 2 Overview (Johnson, Stuart, and Crim 1986) and in the Version 2 User's Guide (Gilbert et al. 1986).

[9]Actually there are three categories as prescriptions that involve timber harvest are further subdivided into prescriptions for existing stands (those that exist at the beginning of the planning horizon) and prescriptions for regenerated stands (those established after the start of the planning horizon).

Yields, Costs, Benefits

In the discussion that follows: yields refers to physical levels of production for an output; benefits refers to returns from the production of outputs; and activities refers to practices and associated costs. Regardless of the version chosen, these three items are represented in much the same fashion and so, will be discussed together.

In Version 1, there is the capability to represent 11 activities or outputs on a decade by decade basis. These can include, for example, output levels of timber, forage available for wildlife, or any other activities or outputs that will change through time. For each of these, additional economic measures representing costs and benefits can be included as appropriate. In addition, Version 1 provides the capability for tracking 10 additional measures such as categories of recreation opportunities (e.g., semi-primitive non-motorized recreation) that will result from application of a prescription to an analysis area. These are viewed as a function of such an application and will not change over time. For more details on this, refer to Section 8 of the Version 1 User's Guide (Kelly et al. 1986).

Again, as with prescription data input, early experience with Version 1 quickly showed that the ability to track more activities and outputs was needed. Therefore, Version 2 was designed to allow up to 200.

Version 2 uses tables similar to those in Version 1 to provide input for matrix generation and report writing. Such tables can be used both with the theming option and when directly entering prescriptions. Beyond this, as was discussed previously, amounts of practices, costs, production levels of goods and services, effects, and benefit values can be entered directly without using yield tables. For more details on this, refer to Section 5 of the Version 2 Overview (Johnson, Stuart, and Crim 1986) or to Section 9 of the Version 2 User's Guide (Gilbert et al. 1986).

Besides these capabilities, Version 2 also offers the user an option (called common economics) for inputting commonly used economic values. This works in a fashion similar to the theming option described above. See Section 3 of the Version 2 User's Guide (Gilbert et al. 1986) for more details on this.

Before concluding the discussion of yield and economic information, two more points need to be made. First, it should be understood that except for a few specialized timber related coefficients[10] neither version of FORPLAN is, in any way, a coefficient generator. Said another way, all yield and economic information is used in the form that it is input by the user. Thus, the second point is that this information represents estimates that are obtained from non-FORPLAN related sources such as simulation models etc.

[10]For Version 1, refer to Appendices II, III, and IV of the Structures and Options Guide (Johnson and Crim 1986) and for Version 2, refer to Section 7.4 of the User's Guide (Gilbert et al. 1986).

Constraints

Three types of constraints can be specified in an LP:[11]

1. Equality constraints.
2. Upper limit constraints (maximum, less than or equal to).
3. Lower limit constraints (minimum, greater than or equal to).

Equality constraints provide a number that must be equaled. Upper limit constraints give a maximum that must not be exceeded. Lower limit constraints give a minimum value that must, at least, be achieved.

There are two general classes of constraints available in either version of FORPLAN.

1. Constraints implicitly designated when the user selects a particular model formulation. For the most part, these constraints relate to land or acreage accounting; i.e., they ensure that only the acres on a given analysis area are represented in the analysis.
2. Constraints explicitly designated by the user. There are a wide variety of these constraints, and they are typically used to incorporate the many restrictions that control management of a forest. Many of these restrictions stem from policy requirements such as the policy to harvest timber under non-declining yield. These constraints are also used to reflect production targets that must be met.

Table 2 shows categories of explicit constraints that can be represented in Version 1 models, while table 3 provides the same information for Version 2. More information on all these constraints can be found in any of the FORPLAN documents cited previously.

Reports

As has been mentioned previously, both versions of FORPLAN offer the user a wide variety of printed reports that may be generated in a given run. Briefly, a set of reports for either version consists of a title page showing the status of the LP solution, a report showing summaries of all the constraints based on the output from FMPS and then a series of tables and graphs.

The first two reports are always produced in Version 1 but may be suppressed in Version 2. However, for either version, the user has the option of specifying how many tables and graphs are to be printed. Following is a brief list of reports that may be obtained when using Version 1.[12]

[11]The material on constraints is taken from the Version 1 Overview (Johnson 1986) and from the Version 2 Overview (Johnson, Stuart, and Crim 1986).

[12]This list and the comments are taken from the Version 1 Overview (Johnson 1986).

Table 2.--Constraints that may be explicitly designated in Version 1.

Constraint	Equality	Lower limit	Upper limit	Function
Prescription acreage	X	X	X	Controls amount or proportion of an analysis area assigned to a prescription.
Analysis area accessibility			X	Sets an upper limit on the proportion of analysis area acreage that could have been treated (in any way) up to and including the period in question.
Cultural treatment and financial				
Acreage restocked			X	Sets an upper limit on the area of nonstocked land that can be regenerated per period on the forest.
Acreage of improved stock planted			X	Sets an upper limit on the area of improved yield that can be regenerated per period on the forest.
Acreage of precommercial thinning			X	Sets an upper limit on the area of precommercial thinning that can be done per period on the forest.
Total cost			X	Sets a maximum budget that can be spent per period on the forest.
Total revenue		X		Sets a minimum revenue that must be obtained per period from the forest.
Scheduled output	X	X	X	Controls the area of timber harvested, volume of timber cut, or volume of some scheduled output produced per period forest-wide or on some portion of the forest. Area constraints can be set up as absolute amounts or as a proportion of the area allocated to specific emphases or intensities.
Inventory acreage	X	X	X	Controls area in specified range of age classes per period forest-wide or on some portion of the forest. Constraints can be set up as absolute amounts of area or as a portion of the area allocated to specific emphases or intensities.
Nonscheduled output	X	X	X	Controls amount of nonscheduled output allowed forest-wide or on some portion of the forest.
Management emphasis and intensity	X	X	X	Controls area allocated to a particular management emphasis or management intensity forest-wide or on some portion of the forest.
Timber harvest flow				
Nondeclining yield		X		Requires that the timber harvest volume produced on the forest not decline from period to period.
Sequential lower bound		X		Requires that the timber harvest volume produced on the forest not decline at more than a certain rate from period to period.
Sequential lower and upper bound		X	X	Requires that the timber harvest volume produced on the forest not decline at more than a certain rate from period to period nor increase at more than a certain rate per period.
Arbitrary control		X	X	Requires that the timber harvest volume per period produced on the forest stay between specified amounts.
Nondeclining yield-sustained yield link	X		X	Requires that the nondeclining yield timber harvest volume produced on the forest in the last period stay at or below the long-term sustained-yield capacity associated with the management intensities and rotation ages selected in the linear programming solution.
Ending inventory		X		Requires that the inventory volume left on the forest at the planning horizon at least equal the average inventory on a forest managed with the management intensities and rotation ages selected in the linear programming solution.
Long-term sustained-yield constraint	X	X		Controls the level of the long-term sustained-yield capacity produced on the forest.
Timber growth constraint	X	X		Controls the timber volume growth per period produced on the forest.

Table 3.--Constraints that may be explicitly designated in Version 2.

Constraint	Equality	Lower limit	Upper limit	Function
Absolute	X	X	X	Control the physical or financial amount of some activity/output that can occur in some period.
Flow	X	X	X	Control the physical or financial rate at which some activity/output can change from period to period.
General relational	X	X	X	Control the proportional relation between two sets of acres, a set of acres and an activity/output or two activity/outputs in some period.
Budget and Revenue				
Total cost	X		X	Sets a maximum budget that can be spent per period.
Total revenue	X	X		Sets a minimum revenue that must be obtained per period.
Allowable sale quantity				
Non-declining yield		X		Requires that the timber sale volume not decline from period to period.
Sequential		X	X	Requires that the timber sale volume not decline at more than a certain rate from period to period nor increase at more than a certain rate from period to period.
Absolute	X	X	X	Requires that the timber sale volume stay between specified amounts in particular periods.
Nondeclining yield - sustained link	X		X	Requires that declining yield timber sale volume in the last period stay below the long-term sustained-yield capacity associated with the management intensities and rotation ages selected in the linear programming solution.
Perpetual timber harvest			X	Requires that the inventory volume left on the forest at the planning horizon at least equal the average inventory on a forest managed with the management intensities and rotation ages selected in the linear programming solution.
Long-term sustained-yield capacity constraint	X	X	X	Controls the level of the long-term sustained-yield capacity.
Timber growth constraint	X	X	X	Controls the timber volume growth as an absolute amount or as a proportion of the long-term sustained-yield capacity.
Prescription controls	X	X	X	Controls amount or proportion of an analysis area assigned to a prescription or group of prescriptions.

Land Allocation Reports

Some reports cover allocation of the land to prescriptions. Reports produced include:

1. Allocation of analysis areas among management emphases.
2. Allocation of aggregate areas among aggregate emphases.[13]

Scheduling Reports

A series of reports deals with the scheduling of management prescriptions over time and the resulting activities, outputs, costs, and returns. Reports produced include:

1. The timber harvest (summary).
2. The timber harvest by prescription.
3. Harvest of existing and future stands.
4. Timber inventory, harvest, and growth.
5. Timber inventory acreage by class.
6. Scheduled outputs (including timber) by prescription.
7. Scheduled outputs (including timber) by identifier.
8. Timber detail by a series of different measures.
9. Cultural treatments.

[13]For details on aggregate areas and aggregate emphases, see Section 4 of the Version 1 MPG (Kent et al. 1985).

Scheduling Graphs

FORPLAN produces a wide variety of scheduling graphs that portray the results over time. Timber RAM (Navon 1971) produced a scheduling graph showing the timber harvest volume in each period and, its popularity with users caused the creation of several additional graphs. Graphs produced include:

1. Total timber harvest volume and sustained yield.
2. Total timber harvest volume, timber growth volume, and timber inventory volume.
3. Area of regeneration.
4. Area of precommercial thinning, release, and other cultural treatment.
5. Area of existing timber in each period that was older than 10 periods at the start of the planning horizon.
6. Timber inventory acreage by age class.
7. Area harvested and timber volume removed by harvest type.
8. Acres harvested and timber volume removed by land class.
9. Acres harvested and timber volume removed by working group.
10. Inventory volume by working group and by land class.

Economic Reports

FORPLAN produces several economic reports covering the planning periods. Reports produced include:

1. Standard cost categories in prescription economic tables.
2. Scheduled output volume, cost, and value.
3. Timber value, total value, and total cost.
4. Net revenue, present net worth, net benefit, and present net benefit.
5. Undiscounted costs and returns.
6. Total discounted costs, total value, and value for each scheduled output by period.
7. Discounted economic data for the planning horizon in total and by scheduled output.

The user has even more flexibility in selecting reports from Version 2. To quote from the Version 2 Overview:[14]

"Beyond a forestwide report that gives the level of each activity and output per period and the associated financial effects, and a forestwide report that gives the levels of different treatment types (such as clearcutting) per period, all reports in Version 2 are optional. Reports similar to the forestwide report can be produced for each prescription in the solution for designated analysis areas or zones and/or for all prescriptions in the solution for designated analysis areas. Also, a wide variety of reports can be created by the user to extract the particular aspects of the problem that are of interest for specified analysis areas or zones. These latter reports can be specified for (1) activities, outputs, and combinations of activities and outputs; (2) acres and volumes by treatment type and stand characteristics; (3) age class acreage; and (4) inventory volume, harvest, and growth."

[14]Johnson, Stuart, and Crim 1986, op. cit.

How Is FORPLAN Used?

FORPLAN is the central analysis tool in Forest Planning. This section provides a brief description of how it is used both for the development of planning alternatives and for accounting purposes. Detailed discussions and case studies are presented in the two Overview documents (Johnson 1986 and Johnson, Stuart, and Crim 1986).

There are 4 planning actions of the 10 identified by the NFMA regulations (USDA FS 1982 36 CFR 219.12) closely associated with these activities and, therefore, with the use of FORPLAN. These are:

1. Analysis of the management situation.
2. Formulation of alternatives.
3. Estimation of effects of alternatives.
4. Evaluation of alternatives.

Analysis of the management situation includes development of benchmark alternatives. These are used to characterize the ability of a given National Forest to produce goods and services. This analysis provides a framework for developing the second set of alternatives during the second planning action in the above list. Alternatives in this second set must cover a wide range of possibilities within the framework developed during benchmark analysis. It is from this second set that a preferred alternative will be selected.

Each alternative, regardless of type, requires one FORPLAN run. Differences between alternatives are reflected in the FORPLAN data primarily by varying the types of prescriptions that are considered and by varying the constraints that are imposed on the model.

LP models (and, therefore, FORPLAN) are useful accounting tools, as has been mentioned previously. That is, the results of the solution can be interpreted by the report writer to provide a wealth of information on items such as production levels of outputs, costs incurred, the allocation of land area to prescriptions, etc. Thus, the information needed[15] to accomplish the planning steps involving the estimation of effects of alternatives and the evolution of

[15]This is true only for those aspects of the planning alternatives that have been quantified and included in the FORPLAN model.

alternatives is in large part, available from reports produced by FORPLAN.

We close this section of the paper with a few observations on the development of a FORPLAN data set and the analysis that follows. Many of these have already been made previously; the purpose here being to provide a summary of some important points. As can be gathered from the preceding discussion, there is a considerable amount and variety of data that must be acquired and organized into a format acceptable to FORPLAN. Therefore, much time and effort goes into just assembling a FORPLAN data set. Once this is done, the data must be edited by the matrix generator and all errors must be corrected. Then several LP runs must be made to calibrate the data set; i.e., to determine both how well it reflects the forest being modeled and how well it addresses the planning problems that have been identified. Only after this is done can actual alternative development be undertaken. Of course, continued refinement of the data set occurs based on the information gained during alternative formulation.

Conclusions

This completes what is intended to be an overview of the two FORPLAN versions and how they are used in Forest Planning. Many topics have either been only briefly mentioned or have not been covered at all. The interested reader can learn more about these topics and the ones discussed in this paper by referring to the papers and publications cited. Also, the other papers present in this symposium will also provide additional information.

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History of the Criteria Defined by NFMA and Used in the Selection and Implementation of FORPLAN

John W. (Bill) Russell[1]

Abstract.--The criteria for selection and implementation of FORPLAN as the primary analysis tool for forest planning initially arose from the conditions which led to the Monongahela lawsuit. Later, the criteria were influenced by NFMA, the NFMA regulations, and by efforts to comply with those regulations. This discussion of the events before and after NFMA provides a non-technical historical perspective of the decision to use FORPLAN and later to develop Version II FORPLAN.

Introduction

FORPLAN was designated as the "primary analysis tool for the Forest plans." The rationale for this decision can best be understood within the context of the events leading up to the National Forest Management Act and those events that occurred during formulation of the regulations. Still other events influenced the many successful applications of this planning tool and the management of implementing FORPLAN.

Three criteria resulted in the designation, use, and development of FORPLAN as the primary analysis tool: (1) the technical, (2) the planning process, and (3) total management needs. The first two, the technical and planning reasons, are criteria either established by, or interpreted as being established, by NFMA and the regulations.

The technical reasons could include, for example, the need for determining allowable sale quantity or long term sustained yield, the effects of minimum management requirements, etc.

Planning process needs might include the consideration of multiple-uses or resources in determining the management emphasis and in scheduling to "form one integrated plan for each unit of the National Forest System" as required by NFMA.

The management reasons might include the need for consistency in Forest planning methods or results to get on with the job of plan development and approval in implementing the National Forest Management Act.

Each of these criteria was influenced by or was an influence on events leading up to NFMA and later the decision about, and the use of, FORPLAN. Therefore, our focus on the reasons for a standard computerized planning model might begin with the planning process and its management as it was between 1970 and 1976.

1971

Unit planning was in progress. There were 1,601 planning units identified in the National Forests. In 1976, there were 493 unit plan draft or final environmental impact statements filed or under preparation and the estimated date of completion of unit planning nationwide was 1985. There were many concerns about the incremental approach of unit planning. For example, the allocation for the last few units of a National Forest might require a total re-analysis for the entire Forest, i.e., "last unit in re-allocation analysis" fear.

Also, at that time there were at least 48 different types of functional plans being required for various purposes. The only resource plan that covered an entire National Forest was the timber management plan. Other resource plans were generally prepared only if significant amounts of the resource existed (General Accounting Office 1978).

Multiple use guides provided general policy direction, but did not set goals for resource development. These were to be established in resource management plans. District Rangers were required to prepare a multiple use survey in which they considered the impacts of proposed projects on the multiple use resources. The guides and surveys did not always result in adequate multiple-use planning. The on-the-ground results that generated increasing public resistance to timber harvest are well illustrated in the challenges that eventually resulted in the NFMA.

Area guide development was also under way.[2] These were designed to be a key interface with other regional programs in study areas. The intent was to aggregate Forest and unit capabilities for use in the RPA Assessment. Much study and development work was underway to make the Forest Service Management Model operational by developing the hierarchy of planning. Standard outputs and activities definitions were defined as information requirements in the Management Information handbook.

[1] Director of Land Management Planning, Southwestern Region, USDA Forest Service.

[2] USDA Forest Service. 1973-1985. Numerous memos, letters and documents.

The Project INFORM (Information for Managers) staff was disbanded in 1975 after marginal success in developing standard resource data bases. This group was initially formed about 1971, the same year the Forest Service Blueprint for Action recommended increased control, compatibility, support and coordination, and training for computer use.

Many line officers in the field were concerned about the appearance of a top down or centralized approach in mandating process. For example, in 1976, one Forest Supervisor wrote, in part, about area planning: "The attempt (by the WO) again seems to be to standardize a process without clearly defining the reasons for doing so...(there is the need to) become "end product oriented," and leave the "how-to's" to those expected to provide him (the Chief) with what he needs."

Just before this at the 1975 summer RF&D meeting held at Fort Collins at the Computer Center, the focus had been on Systems Development, Organization, and Management. At this meeting, the Chief and RF&D were provided with descriptions of some thirty plus different planning processes, flow charts, and PERT diagrams; a bewildering display of apparent inconsistency in planning approaches. A major objective of the meeting was to decide how to (1) organize; i.e., centralize or decentralize systems training and development staffing, (2) determine the level of effort needed, and (3) establish a time frame for implementation of actions or programs.

Besides recognizing the number and diversity of planning processes, other areas of concern at this RF&D meeting were: the lack of uniformity of data definitions and standards; lack of data and analytical support for assessment and program development and subsequent allocation; fragmented independent design efforts in developing a coordinated management information system; and a basic disagreement on computer system management and lack of adequate effort to develop, operate, and trouble shoot computer systems including lack of training.

The Systems Development Action Planning Team (SDAPT) was chartered to examine these problems in greater detail and make recommendations for their resolution. This team was headed by Doug Liesz, Regional Forester in Region Five at that time. The team recommended strengthening national leadership for hardware, software and data bases. A major reorganization and redefinition of national responsibilities resulted. A second Associate Deputy Chief for Administration was assigned responsibilities for systems. (The SDAPT recommendations were revisited during the Systems Review Team effort chaired by Regional Forester Jean Hassell in 1984. The original SDAPT team felt their recommendations had been mostly met but there were new challenges.)

The General Situation, 1970-1976.

Now enters the Court of Appeals for the Fourth Circuit ruling on the Monongahela, the NFMA amendment to the Resources Planning Act, and the requirement for an interdisciplinary planning process and an integrated plan for each administrative unit. Final planning regulations (or semi-final, depending on your point of view) were issued on September 17, 1979 (Oregon Law Review 1985). These regulations were revised and promulgated again on September 30, 1982.

Before passage of NFMA, various staffs in the Washington Office under the leadership of Timber Management and Land Management Planning, had been working on strategy plans to implement NFMA. These plans were also used to provide information to Legislative Affairs on the effects of choices being considered in the legislation.

The strategies depended heavily on field input, such as a series of questionnaires responded to by Forest resource staff specialists, District Rangers, and Regional Office planning specialists from around the country. In addition, the new Systems Application Unit for Land Management Planning (SAU-LMP) provided staff support for formulating national strategy. This unit was formed primarily from the Watershed Development Unit that was moved from Berkeley, California, to Fort Collins, Colo. in 1973. This unit was responsible for the Resource Capability System, later renamed Resource Allocation Analysis.

Responses from the various field sources generally focused on the need to eliminate functional resource inventories and incremental planning. Several papers written by SAU-LMP (Bottoms 1975) formed a basis for using a "systems approach" to "natural resource decision analysis" including the need for mathematical solutions as a basis for resource allocation and similar decisions. This philosophy provided the core concept of the proposed integrated planning process before and after passage of NFMA.

Initially, a WO strategy and tactics overview provided coordination direction and responsibility for various staffs working at all levels of the organization. A work plan for Implementation of the NFMA provided more specific direction. For example, several end products needed for implementing NFMA were described with the primary responsibility for the final product, for developing and maintaining the product, assistance to be provided, staffs to advise and review, and the final approving authority, e.g., Regional Forester, Deputy Chief, or Chief.

The end products identified included Lead Forest Work Plans, Forest Planning Criteria, revised Forest Service Manual 1900, Draft FSM 1920, Regulation comments (also for use with the Committee of Scientists), RARE II data base, Regional Plans, Lead Forest draft and final environmental impact statements and Forest Plan, and revised FSM direction for each resource area.

A network of coordinators was set up for communication. This included a 1900 core team including coordinators from all Deputy areas, and a resource team (or interdisciplinary team) within the NFS Deputy Chief area of responsibility. Associate Deputy Chiefs provided a steering or oversight function. The Regional Planners and the Forest Planners and Forest Supervisors for Lead Forests were a part of the coordinating network.

The lead Forest planning program was established to "provide a basis for the incorporation of recommendations and guidelines in the FSM and FS Handbook." The objective of monitoring the procedures used by lead Forests was to (1) test the feasibility and effectiveness of the

applied methods and procedures used to produce a given product (DEIS, FEIS, or Forest Plan): and (2) to evaluate feasibility and practicality of the NFMA regulations. Periodically the Lead Forests met to compare notes, experiences and products and the proceedings were documented and distributed.

There were as many variations in techniques as there were lead Forests (initially one from each Region). Other Forests were not sitting idly by either. Many Forests felt obligated to begin planning for many reasons. The techniques used varied from mapping overlays similar to techniques used in urban planning and more sophisticated computer mapping techniques such as MIADS2 and its modifications. The techniques also included the use of a budget programming method, i.e., ADVENT, and other mathematical techniques, including Goal Programming.

There was some very good planning going on. The National policy had been to permit each region to experiment how planning was to be accomplished to promote innovation. The only standard for planning was past plans and a "good" plan was the standard only until a "better" plan was done (General Accounting Office 1978).

Based on the experience of lead Forests in attempting to meet the new NFMA regulations, Timber Management and Land Management Planning agreed that some standard approach was needed if Forest Plans were going to have any common basis and be usable for the RPA Assessment, RPA Program, and budget proposals.

First Regulations Issued September 17, 1979

The regulations developed for NFMA were interpreted to require an optimization technique for both allocation and for scheduling. Experiences in unit planning used such allocation techniques to assign management emphasis to land areas. Timber management planning had also historically used optimization for timber harvest scheduling. The regulations were developed knowing that these two basic needs and approaches represented the state of the art in planning.

The practical choices of optimization techniques were limited to three systems: (1) Integrated Resource Planning Model (IRPM) (Kirby et al. 1980), Resources Capability System (RCS or RAA), and (3) Timber Resource Allocation Method (RAM) (Navon 1971) or an ongoing revision of RAM called Multiple-Use Sustained-Yield resource scheduling Calculation (MUSYC) (Johnson and Jones 1979, Iverson and Alston 1986, Johnson et al. 1986).

Although RCS had been used in several unit plans and on at least two national forests for planning, Timber RAM had been widely used and represented the greatest reservoir of experience and skill in optimization use in the Forest Service at that time. MUSYC provided some capability for multiple-use analysis already. Besides meeting the intensive requirements for timber harvest analysis required in NFMA and the regulations, MUSYC could be modified to consider other resources equally and simultaneously to meet other requirements. Not only were there people trained and already using RAM/MUSYC, there was ongoing commitment by the Forest Service and by Norm Johnson to provide support for its use and improvement.

So RAM/MUSYC was renamed FORPLAN and responsibility for its support was shifted from TM to LMP. For many technical reasons Version II of FORPLAN was later developed, including the need for easier data entry, spatial definition, increased capacity for other resource or use variables and other needs identified by forest analysts. Not the least of these reasons was the ability to use the standard outputs and activities of the MIH to provide a direct link to the budget and RPA. It was also hoped that Version II would be more readily learned and promote interaction between forest interdisciplinary team members.

Each Forest Supervisor and planning staff went through two weeks of awareness training that included discussions of optimization. Computer conferences were used to provide up-to-date training and to identify and solve problems in software and computer use. National and regional training sessions on the use of FORPLAN were held. The WO Systems Application Unit for Land Management Planning provided direct assistance to many forests both by phone and by travel to the unit. A hot-line for FORPLAN handled as many as 200 or more phone calls per day. A Version-Release system enabled users to know precisely what worked and what did not and provided a key to the documentation that was constantly being revised in response to suggestions by forest planners and analysts.

When new and more stringent national standards and guidelines dramatically increased the emphasis on economic values and analysis, most Forests were forced to totally re-formulate their planning models to comply. As draft plans were reviewed, planning models were revised, supplemented, or even re-formulated again. Some draft plans were re-drafted and re-issued.

The "Human Element"

Recalling these hectic times of turmoil and change in forest planning and analysis prompts a word or two about the "human element" of FORPLAN that tends to be overlooked in most discussions and writings on the subject. This refers to the enthusiasm of planners and analysts on the national forests; the frustrations and blood, sweat and tears of those people; referring to the long days and nights and weekends that so many people put in because they believed in what they were doing; referring to the personal stress that manifested itself differently in different people but inevitably took its toll in each of us who were committed to doing the job right.

This subject probably requires a separate and undoubtedly lengthy paper. But for those who know who you are, you will remember when you hear or read this that the story of FORPLAN is not computers, or models, or data; it is dedicated people who care about doing good professional analysis. Many of these people came to support a standardized approach to a complex problem. It was the most efficient way to adapt to changes in national direction and need, a philosophy that continues to be useful.

Today and Tomorrow

However, even with these constant shifts toward standard use of a required analytical tool, i.e., more standard model formulation, there is today, a great variation in results. Regional summaries of draft and final planning data for use in program proposals, budget allocation, and other management information have pointed out differences Forest by Forest.

Besides the need to add up or summarize outputs and costs, acreage summaries are increasingly important. One important thing learned from Forest Plans is that many people did not know what the Forest Service did until we showed them our draft plans. Now we must be able to show them we have made progress in the past and plan to make more progress in managing unsuitable or unsatisfactory conditions, e.g., watershed, grazing, wildlife habitat, etc.

As we monitor and amend Forest Plans, some of these pressures and management needs will require us to continue to standardize our resource data and management information. Experience with a standard computerized model to date indicates we will still have differences ten years or so from now. But there are a lot of useful similarities in planning process and management information today as a result of yesterdays decisions to standardize.

There is an increased need for the expertise gained in Forest Planning. Analysts must do more than assemble data and provide results. Analysts must move closer to decisionmaking and into a mainstream information management role. We have done a good job in Forest Planning, and with the expertise and the communication and computing power we now have, the opportunities are even greater to do a better job in the future.

Conclusions

The selection and use of FORPLAN effectively met most if not all the technical, planning, and management criteria, especially as Version II was developed and implemented. FORPLAN provided an opportunity for uniform consistent analysis, yet allowed each forest planning team to adapt the model to their needs. It increased the opportunity to link RPA, Forest Plans, and the budget process. The planning needs of unit planning, timber harvest scheduling, and other resource objectives were pulled together in an integrated analysis. FORPLAN provided a basis for complying with NFMA requirements including the need for an interdisciplinary approach. It's use increased the analytical skills in the Forest Service and stimulated most resource specialists to increase their ability to quantify resource relationships and objectives. The decision to use FORPLAN will continue to provide benefits in the future. The benefits will be even greater if the Forest Service continues using it, because the initial costs and frustrations are well behind us and we can take advantage of all that has occurred.

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The Committee of Scientists Perspective on the Analytical Requirements for Forest Planning

Dennis E. Teeguarden[1]

Abstract.--The analysis and documentation required in NFMA planning regulations can be classified into 24 generic categories. FORPLAN's capacity to meet analysis requirements at the forest level is very strong, particularly those related to timber harvest and activity scheduling, formulation of bench-marks and planning alternatives, and selection of vegetation management prescriptions. For 12 of the categories, FORPLAN can contribute, but must be coupled to other models or analytical procedures.

My assignment is to provide background on the legal and analytical requirements for forest planning on the National Forest System. I start by commenting on the work of the National Forest Management Act Committee of Scientists (COS), and follow with observations about alternative strategic approaches to planning. I then discuss the NFMA planning requirements in broad generic categories and assess, perhaps unwisely, FORPLAN's capacity to satisfy those requirements. I then conclude by asking, "Will comprehensive planning work?"

A disclaimer is in order; I am not speaking for the former COS. The discussion and analysis to follow reflects only my perspectives rather than those of my colleagues. However, the COS functioned with nearly complete unanimity regarding the implementing regulations for forest planning. I think the other members would agree with much of what I say here.

The Committee of Scientists

The COS was appointed to advise the Secretary of Agriculture on rules and regulations for implementing Section 6 of the National Forest Management Act of 1976. The Committee started its work in May, 1977, largely completed its duties in August, 1979, and was discharged by the Secretary following publication of the first rules in the *Federal Register* in September, 1979.

The COS was not a policy-making body. It's work was conducted in two related phases. First, we worked with Forest Service staff in preparing language to be considered for incorporation in the draft regulations. Congress probably envisioned a more reactive role us, but it turned out to be the only practical way to operate. Second, we evaluated and recommended changes in the draft regulations proposed by the Secretary. All 18 meetings were open to the public.

In late June, 1982, the former COS was recalled as consulting group for a three-day public meeting held in Washington, D.C. to give advice on the Reagan Administration's proposed revision of the NFMA regulations. The revisions involved substantive changes concerning regional plans, economic efficiency analysis, and management requirements for wildlife. Also, the rules, which were published in revised form on September 17, 1982 were reorganized, simplified, and clarified (USDA Forest Service 1982).

The seven COS members were drawn from the forestry schools and natural resource colleges. They were Art Cooper (North Carolina State U.), who served as Chairman; Thad Box (Utah State U.), Rodney Foil (Mississippi State U.); Ronald Stark (U. of Idaho); Earl Stone (Cornell U.); William Webb (New York State U. at Syracuse), and I.

The Committee was a multi- and interdisciplinary group. Six of the seven were biological scientists with experience in entomology, range ecology, soils, silviculture, wildlife, or forest ecology. I represented forestry economics, and was the only person with some experience in mathematical modeling of forest management problems. None of us were professional planners or system modelers. However, the duties of the COS did not involve either model specification or development, but rather the issues to be addressed, procedures, standards, monitoring, and documentation. It's task was to assure that the planning rules, guidelines, standards, and procedures rested on the best that scientific knowledge and an interdisciplinary point of view could offer at the time.

Then, and perhaps even now, two fundamentally different legal structures for planning were in a state of contention. One had a **prescriptive** orientation; it would define acceptable land-use and forest management practices by law. The second was **procedural**; it would establish planning requirements, procedures, and standards, but assign responsibility for decision-making to the judgment of resource professionals. With some exceptions, notably streamside protection and maximum size of clearcuts, NFMA largely adopted the procedural structure. The COS adopted the same philosophy; wherever NFMA permitted, it recommended process-oriented rules and guidelines for planning rather than prescriptions. Some critics thought the rules to be too process-oriented.

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However, we believed that NFMA and its legislative history mandated a process-oriented approach.

Planning Theory

There are two radically different models for planning and resource allocation on public land. The first, "incrementalism," would take existing land-use allocations, inputs and outputs, and programs as fixed and already sufficiently rationalized by the test of past experience. If adjustments are necessary, these can be considered on a site-by-site, case-by-case basis drawing on past experience in similar situations. Normally, only marginal adjustments need be made in each planning period, although the cumulative effect over time of such changes could significantly alter land-use allocations and practices.

The second model, "rational comprehensive" (Lindbloom 1959), in effect was adopted by congress in NFMA. The many, complex requirements of NFMA call for planning that is systematically comprehensive, and for decisions that are rationalized in terms of specific objectives and criteria. Thus the implementing regulations adopt a "zero-based" systematic planning procedure (Cortner and Schweitzer 1983) which:

1. Defines the objective or values to be maximized;
2. Identifies the full range of possible alternatives for achieving the desired objective(s);
3. Comprehensively evaluates the physical, environmental, social, and economic consequences of each alternative; and
4. Chooses the course of action which best realizes objectives.

Model Selection

The COS did not formally discuss or attempt to evaluate any specific modeling approach for implementing the analytical requirements of NFMA. The committee was aware of Norman Johnson's work to develop what eventually became FORPLAN (Johnson 1986), and it was intensively involved in constructing rules for timber harvest scheduling and development of silvicultural prescriptions. However, the decision of Associate Chief Douglas Leisz in December, 1979 to designate FORPLAN as the required analysis tool to be used for forest planning came after the Committee had finished its assignment.

I am reasonably confident that if the COS had considered the **generic** characteristics of the ideal analytical model it would have recommended the following key structural capabilities: (1) simultaneous multi-resource land allocation, activity scheduling, and prescription selection analysis; (2) analysis of both spatial and temporal allocation problems, including effect of predetermined policy constraints such as non-declining yield; (3) establishment and analysis of vertical linkages between forest, regional, and national level models; (4) establishment of horizontal linkages to other national forests and the private sector in a region; (5) economic efficiency analysis, including the establishment of cost-efficient alternatives; (6) economic and social impact analysis, including such things as impacts on employment, income, and changes in the distribution of benefits and costs; (7) documentation of analysis assumptions, standards, relationships, and data; and finally, (8) storage and retrieval of inventory data. In a moment, I will comment on FORPLAN's capacity to meet these and other analytical requirements.

John Russell (1986) has discussed why the Forest Service decided to develop an optimization model to satisfy these demanding analytical capabilities, and also the rationale for selecting MUSYC as the basis for developing what eventually became FORPLAN. NFMA and the implementing regulations require some form of mathematical modeling of the land management system to insure program feasibility, incorporate technical relationships, reflect resources availability, insure decisions are consistent with policy objectives and constraints, and for conducting trade-off analyses. Also, the model must have a capability for handling analyzing timber management programs, including temporal harvest scheduling, identification of suitable timberlands, rotation policy, and selection of appropriate silvicultural systems.

The COS regarded systematic analysis of timber issues as central to the planning process for three reasons. First, timber issues were central to the concerns that produced NFMA. Second, timber harvesting is the most important vegetation management activity that influences other outputs and resource values. Third, the Act contained more detailed, intensive requirements for timber than for any other resource. Thus, from my perspective, the already developed capabilities of MUSYC made it a logical choice for the new R&D work that would be necessary to meet the model specifications I have outlined.

FORPLAN and Planning Requirements

The analysis and documentation requirements stipulated in the NFMA planning regulations include several hundred different but often related items. Some were established in NFMA; others came in through the rule making process. It is impossible in the time available today to consider them all in detail. I assume that most of you are familiar with the NFMA regulations. I know that many of you have had experience in attempting to implement them in the planning process.

Table 1 lists the analytical requirements for forest planning in terms of a few generic categories. Another person might define these categories differently, and some overlap. Perhaps a few important items, such as mineral resources, have been left out. But I think the list captures most key analytical requirements of the NFMA regulations. Looked at another way, it provides a sort of check-off list for the development of analysis procedures and for the evaluation of simulation/optimization models that are used in support of planning and decisionmaking.

The first 19 items relate to analysis and planning at the forest level, while the others necessarily involve larger geographic units including possibly a region or whole state.

Table 1.--Analytical requirements for forest planning.

Requirements		FORPLAN Capability
1.	Interdisciplinarity	O
2.	Multi-resource coordinated planning	O
3.	Define resource production capabilities	..
4.	Establish benchmarks	..
5.	Alternative design and evaluation (trade-offs)	..
6.	Economic efficiency analysis	..
7.	Establish price/quantity demand functions	O
8.	Environmental impact analysis	O
9.	Meet management standards (constraints)	O
10.	Timber harvest and activity scheduling	..
11.	Establish vegetation management practices	..
12.	Identify land unsuitable for timber production	..
13.	Non-timber production/activity scheduling	..
14.	Potential Wilderness area evaluation	O
15.	Visual resource analysis	O
16.	Cultural/other resource interactions	O
17.	Analyze cumulative effects within a forest	O
18.	Inventory and information storage and retrieval	O
19.	Plan documentation	O
20.	Species diversity analysis	O
21.	Determine viable vertebrate population levels	X
22.	Economic impact analysis	O
23.	Federal/state/private coordination	X
24.	Analyze cumulative effects within a region	X

.. Independent potential capability to satisfy requirement.
0 Contributes but must be coupled with other models and/or analytical procedures.
X Not potentially capable.

Many requirements, particularly those related to timber, are highly specific and susceptible to quantification and analysis in an optimization framework. Others, such as those related to wildlife outputs, wilderness allocation, or recreation, are not as readily quantified or optimized. Two items, cumulative effects within a forest and across different forests within a region are not explicitly mentioned in NFA or the regulations; but I have included them both because cumulative effects have recently risen as issue in Idaho and because the requirement for federal/state/private coordination implicitly calls for analysis of cumulative impacts.

A simulation or optimizing model such as FORPLAN, creatively used by knowledgeable persons, provides a powerful tool for forest planning. However, the nature of the planning problem makes it unlikely than any single model will ever satisfy all the requirements. It is probably best to think of the planner/decision-maker as operating in an environment of several different models or processes. Some, such as FORPLAN or input-output models such as IMPLAN, will be quantitative and objective in nature, while others are qualitative and subjective.

FORPLAN's potential for meeting forest planning requirements depends on: (a) its inherent characteristics; (b) availability of data, and (c) the manner in which it is used. In Table 1, I have attempted a general assessment of Version 2's potential capacity **without regard to data availability or current practice.** Others, no doubt, will speak to those issues. The assessment is intended only as a framework for discussion. No doubt others will rate the criteria differently than I have.

FORPLAN is very strong in meeting analytical requirements at the forest level (items 1-19), particularly those relating to analysis of production capabilities, benchmarks, formulation of alternatives, timber harvest and activity scheduling, selection of vegetation management prescriptions (particularly those related to timber), non-timber activity scheduling, and economic efficiency analysis. This reflects its origins in RAM and MUSYC, and the susceptibility of modeling these elements in a linear, programming framework.

For many other key requirements, 12 or one-half of the generic categories, FORPLAN can contribute but must be coupled to other models or exogenous analytical procedures or processes. For example, FORPLAN has no inherent capacity for local or regional economic impact analysis, but its numerical results can be fed into an input-output model that can do that task. FORPLAN by itself cannot assure a balanced, interdisciplinary approach to forest planning, which is largely determined by the planning team's composition, perspective and political context. However, FORPLAN's analytical capacity for multi-resource coordinated planning and for trade-off analysis is

consistent with the requirement for an interdisciplinary approach to planning

Similarly, FORPLAN version 1 allows for the specification of step-wise linear approximations of demand curves for timber, and version 2 for any output. However, as for timber yield functions, formulating the demand functions requires an independent analysis and modeling procedure. So far little attention has been given to the demand side of forest planning. Demand curves are usually represented in two step form: quantities up to the amount produced are assumed to be sold at a fixed average price, while quantities greater than that amount have zero value (Wilson 1986). In effect, it is assumed that price, whether market-determined or assigned, is invariant concerning the plan's outputs. This may be an appropriate assumption for a commodity such as timber, which is sold to a regional or national market, but not for recreation or wildlife which tend to valued by local or state level demand. In the future, more attention needs to be given to modeling the demand side of forest planning.

It would appear that in only three areas is FORPLAN in its present form incapable of meeting an analysis requirement: determination of viable vertebrate population levels; analysis of regional cumulative impacts; and federal/state/private coordination, including interactions between forests and between federal and private sectors.

The revised regulations expanded and clarified the analytical requirements for wildlife. To maintain viable populations of wildlife requires expressing threshold population levels in terms of habitat needs and management prescriptions. Such determinations must be made at least in part on a subjective basis outside of FORPLAN.

Once wildlife targets are quantified, FORPLAN can be used to simulate effects on other outputs and opportunity costs. However, FORPLAN has limited capacity for optimizing fish and wildlife population levels or species diversity. Both of these issues must be addressed at the forest and regional level, as illustrated by the case of the spotted owl in the Pacific Coast states.

Section 219.7 of the NFMA regulations calls for the Forest Service to "coordinate regional and forest planning with the equivalent and related planning efforts of other Federal agencies, State and local governments, and Indian tribes." The term "coordinate" would appear to imply some formal effort to integrate forest plans with the situation and objectives on other public and private land within the individual forest's area of influence, and to take account of the cumulative impact of all forest plans within a region or state.

Most states have not developed the necessary institutions or data base for coordinated planning, so the first forest plans have had to rely on informal, subjective, ad hoc processes. However, the California Department of Forestry's new Forest Resources Assessment and Analysis group is developing a state level data base, and models for analyzing the effects of alternative programs and policies on privately owned forest and range lands. The model will be linked to the 1985 national forest plans in California, offering the possibility of examining the impact of those plans at the state level. (Larry Davis will report on this project tomorrow). Also, Idaho has asked for an analysis of the cumulative effect of the new forest plans at the state level, and undoubtedly other states (including California and Oregon) with substantial national forest land will soon follow suit.

FORPLAN was designed to analyze resource allocation issues at the forest level. In the present form, it has no potential for integrated analysis or planning at regional or state levels, or for the examination of cumulative impacts. As these issues surface and take political form, as in Idaho, an R&D program to develop the necessary models and analysis procedures will be necessary.

Future planning on the national forests undoubtedly will move from its present largely exclusive emphasis on the individual forest unit toward integrated planning that formally recognizes linkages between the federal and private sector and cumulative impacts of federal actions on state economies. This is not to say there will be more centralized planning than now, but rather that there will be more emphasis on developing national forest plans that explicitly consider expected programs on other federal and private lands, and cumulative impacts on state economies and markets.

Will Comprehensive Planning Work?[2]

The NFMA planning and economic analysis requirements are numerous and complex. As pointed out by Cortner and Schweitzer (1983) the data required "are far beyond those ever compiled by the Forest Service or anyone else....". Some critics worry that the necessity for comprehensiveness, inadequate data, and imperfect methodology will inspire litigation to the extent that the whole planning system will breakdown.

Behan (1981) has even suggested that NFMA be repealed on grounds that this would eliminate the possibility of litigation, keep resource management out of the courtroom and refocus planning on "...the considered judgment of professional land managers.." rather than jumping through the hoops of the planning regulations.

However, it was litigation over timber harvesting practices on the Monongahela National Forest in *Issac Walton League versus Butz* that led Senator Humphrey to sponsor NFMA. Even without NFMA, an advocate with a smart lawyer will find some law to serve as a basis for litigation, as did the Issac Walton League. Further, even without NFMA, NEPA would require much the same planning process anyway. So the choice does not involve whether there should be a law, but rather how the law should be structured to foster the public interest in good management, rational decision making, and minimum interference by litigation.

I am much attracted to the NFMA procedural approach to planning for several reasons. First, it is the most democratic, because the key decision are made at the forest level where the interactions, trade-offs, and effects can best be evaluated by those who must carry out programs and bear the consequences. Second, it places great reliance on

[2]This section is drawn nearly verbatim from Teeguarden (1985, p. 280-283).

the skill, knowledge, and ethics of the professional resource planner. Third, with its emphasis on systematic, comprehensive problem-solving, it provides maximum opportunity for the application of economic efficiency analysis to the design of alternative plans and to the decision-making process.

If the NFA planning system doesn't work, it will be a major set back for the forestry profession, because a more prescriptive law surely will follow. In 1979, the COS warned that the process would be costly and imperfect. It also called for patience and cooperation in a continuous shared effort to improve data and analytical procedures.

The Forest Service has had good support as it has attempted to conduct the planning process under constantly changing edicts from Washington. Very soon, when the first round of NFMA plans is completed, there will be an opportunity to comprehensively evaluate how well the new system has done. That, in turn, will provide an opportunity to consider whether changes in the law or regulations are merited by the experience of planners, who had the formidable task of using imperfect planning arts to developed a technically sound, politically acceptable portrait of future resource management on the national forests.

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Technical Criteria Used in the Development and Implementation of FORPLAN, Version 1

Daniel B. Jones[1]

Abstract.--FORPLAN was influenced by modeling efforts in three areas: timber activity scheduling, area and unit planning, and transportation planning. A chronological summary is presented of some techniques and features of modeling and analysis which influenced the evolutionary development of FORPLAN. Computer and other considerations are briefly discussed and documentation is described.

The National Forest Management Act of 1976 was aimed at improving the Forest level planning process by reinforcing the principles of the Multiple-Use Act and requiring integrated planning by interdisciplinary teams. Passage of the Act created much interest in techniques that could solve the analytical problems implied in the law and regulations. For several years after it was enacted, there was considerable interest in evaluating existing analytical models and in developing new ones to help in planning.

Bill Russell just presented a discussion of the changing character of The National Forest management problem. Another excellent discussion of this and the technical evolution of analytical models developed for planning within the Forest Service, is presented in "The Genesis of FORPLAN: A Historical and Analytical Review of USDA Forest Service Planning Models" (Iverson and Alston 1986).

It is important to recognize that development was a dynamic process. FORPLAN provided a structure to build individual forest models, but innovative users found new ways to use the system and often identified problems and new techniques. As users encountered limitations, the developers attempted to solve their problems. As users gained experience and management got more involved, the process quickened.

To say that development was dynamic is probably an understatement. An expression used at the time was that using FORPLAN was like trying to ride a bicycle while it was being built. One never really knew what parts were there or whether they were working. An incident that comes to mind involves an analyst on one of the Forests. He was working late one night and gave me a call to report a problem with FORPLAN. I told him I would see if I could find the problem and call him back when I got it fixed. After I corrected the program I gave him a call. He had told me that he would be the only one left in the building; so, I should let the phone keep ringing until he could get to it. Well, I let the phone ring quite a long time, but he finally answered and said, "Hold on a minute. I was down the hall when I heard the phone ring, and I have to get my pants back on." To me that summarizes the development of FORPLAN-- we never had a chance to get our pants on.

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Influences on FORPLAN

To understand the technical criteria used in the evolutionary development of FORPLAN, we first need to understand the important basic technical criteria in the models that influenced FORPLAN. If some of the terminology is not clear to the reader, the references for this paper and other papers presented at this symposium should provide the explanations needed to clarify it.

As Bill Russell described in his paper, the major development of planning models took place in 3 areas: (1) timber activity scheduling, (2) area and unit planning, and (3) transportation planning. FORPLAN's evolution was influenced by all three types of models.

Timber Activity Scheduling

FORPLAN's roots are deeply imbedded in two timber activity scheduling models: Timber Resource Allocation Method--RAM (Navon 1971) and the Multiple-Use Sustained-Yield resource scheduling Calculation, called MUSYC.[2] Timber RAM was used by most National Forests in the 1970's to help set their timber harvest levels and determine sustainability of harvest levels over time. Its use led to the acceptance of and reliance on linear programming (LP) as an analytical technique, at least in timber management.

In 1975, Johnson and others began work on MUSYC, in cooperation with the timber management staff. MUSYC was a linear programming-based approach designed to overcome structural and analytical limitations of Timber RAM while providing more land categories and constraints to help deal with clearcutting and land classification controversies that were surfacing (Johnson 1986),

With increasing pressure to control clearcutting, and to develop different management practices for different inventory categories, timber planners requested the ability to specify constraints that would reflect these emerging

[2]Johnson, K. Norman and Daniel B. Jones. 1979. Timber harvest scheduling model users' guide and operations manual [MUSYC]. Draft manuscript. 158 p.

restrictions on timber harvest. To allow for this, the capability was provided to define each inventory category by three identifiers: working group, land class, and condition class. In addition, each possible treatment could be named by a treatment type. User-defined constraints were provided to enable restriction of the acres or volume treated by treatment type, by groups of identifiers, or forest-wide. Also, reports were provided for groups of inventory categories by treatment type, and for the acres in each age class per period. These inventory treatment type and age class distribution reports helped in interpreting the solutions and determining their effects.

Timber RAM, and to a great extent MUSYC, were used primarily to determine potential timber harvest volumes and determine sustainability of harvest levels over time. Other resources were not included explicitly in the models, but rather through timber yield adjustments and constraints on timber treatment. Effects on non-timber resources were inferred from the reports.

Area and Unit Planning

FORPLAN's development was also influenced by area and unit planning models, particularly the Resource Capability System (RCS) developed by the Watershed Systems Development Unit at Berkeley, California (1972). Iverson and Alston (1986) emphasize that the developers of RCS were among the leaders in the movement toward interdisciplinary team efforts at problem solving, and away from single-function planning approaches. RCS was a multi-resource model designed to simulate the response of on-the-ground resource analysis units to alternative management strategies. The RCS resource analysis areas were often the basis for classifying land use zones for unit planning purposes. A version of the system without response simulation models was created and called the Resource Allocation Analysis System (RAA).

Johnson (1986) points out that detailed timber activity scheduling was not emphasized in RAA and thus it did not fulfill the needs of timber management, including volume control. However, emphasis of RAA on equal treatment of multi-resource activities and outputs, the portrayal of yields as "timestreams," area control, and the concept of zones, or contiguous areas of the forest, were technical criteria recognized as being needed in FORPLAN.

Transportation Planning

The Integrated Resource Planning Model (IRPM) (Kirby et al. 1980) is another model that influenced development of FORPLAN. This model was developed by the Management Sciences Staff located at the Pacific Southwest Forest and Range Experiment Station. Johnson (1986) describes the model as being created through the merger of a Forest Service budgeting model with a road engineering transportation model.

Weintraub and Navon (1976) added some features to Timber RAM to explicitly consider construction of a transportation network with timber activity scheduling. This system was called Roading Timber RAM.[3]

The emphasis on spatial location of activities in IRPM and Roading Timber RAM was a concept incorporated into FORPLAN (Johnson 1986; Johnson and Crim[4]).

Chronological Development of FORPLAN

The following is a chronological discussion of the evolutionary development of FORPLAN Version 1, focusing on technical criteria. Describing the criteria chronologically should provide an evolutionary and technical perspective. The interpretation of events is my own, and others may have different interpretations, depending on their own perspective.

1978

The evolution from MUSYC to FORPLAN seemed very gradual to this author. If there was any single event that precipitated a change, it was the decision by Timber Management and Land Management Planning in fall 1978, to conduct a three month study to evaluate different ways to link allocation and scheduling models and thus address the dual problem of allocation and short term scheduling feasibility versus long term sustainability of timber harvest levels.[5,6] The purpose of this study was:

> "to develop and assess procedures which: (1) link resource allocation (land, capital, manpower) and output scheduling, and (2) result in an integrated forest plan that is feasible from an operational perspective. ... Since this study needs to be completed in a timely fashion...[it is] concerned with developing and assessing resource allocation and scheduling procedures on national forests where timber is a principal concern, and only linear programming procedures will be considered."

Four approaches to linking land allocation and output scheduling were proposed:

1. A two-part approach with static allocation and output scheduling models. The land allocation from the allocation model is used as input to the scheduling model. The schedule is thus dependent on the allocation, that is, allocation is pre-emptive.

2. A two-part approach linking an allocation and short term scheduling model with a long term timber harvest scheduling model to determine

[3]Navon, Daniel I. 1980. Integrating timber and transportation planning. Draft manuscript. August, 1980.

[4]Johnson, K. Norman and Sarah A. Crim. 1980. Considerations of Roading in FORPLAN. Unpublished manuscript. September 15. 18 p.

[5]Crim, Sarah A. 1986. Personal communications, April, 1986.

[6]USDA Forest Service. 1978. Draft joint study proposal between Timber Management and Land Management Planning (untitled). 8 p.

sustainability of harvest levels. In the initial model, land allocations needed to meet alternative forest targets and output schedules for the RPA planning horizon are determined. The acreage allocation and short term schedule become input to Model II (MUSYC) where schedules could be refined and long term sustainability could be determined.

3. A one-part approach with explicit recognition of two "levels" of decision variables. Land allocations and output scheduling are done simultaneously. Each "level one" variable accounts for the proportion of each acre allocated that occurs within a particular timber stand grouping. These stand grouping acres are summed across analysis areas and made available to an appropriate set of "level two" variables. This eventually became the "aggregate emphasis" approach.

4. A one-part approach with one "level" of decision variables. This approach also arrives at a simultaneous allocation of land and schedule of output flows. It came to be called the "basic simultaneous" approach.

The issues to be addressed in the study were: (1) timing of output flows, (2) vicinity in allocation and scheduling, (3) objective function formulations, (4) operational feasibility, and (5) structural capability of each approach.

As part of this study, a steady-state allocation model was built for the Gospel Hump Study Area which also was modeled in MUSYC. Modifications to MUSYC were begun to provide linkages to the steady-state model. The study launched the FORPLAN development effort.

1979

During 1979 much of the basic structure of FORPLAN was developed. In the overview document for Version 1, Johnson (1986) states:

> "The Forest Planning Model (FORPLAN) was developed to provide an analytical structure which portrayed the multiple-use interactions that determine the range of choice in forest resource management. Classical timber harvest scheduling characteristics were retained to enable specification of efficient, sustainable schedules, but now within the broader context required by integrated planning. Starting with the basic analytical structure of MUSYC, improvements were made in how resources other than timber were represented and in definition of land areas. These improvements recognized: (1) choices other than harvesting and growing timber, (2) outputs other than timber, (3) values for outputs other than timber, (4) land other than commercial timberland, (5) geographic areas within the forest for reports and controls, and (6) geographic areas within the forest for allocation decisions (Johnson 1986)."

A 2-week training session for MUSYC was held in February, at Utah State University (USU). Johnson outlined the linkage study and some of the changes being considered for the system at that session. Tom Stuart, analyst on the Lolo National Forest, volunteered to participate in the project, using a large allocation model which would be linked to MUSYC via some common linkage rows. Acres allocated for timber production in the allocation model were transferred to the scheduling model through common linkage rows, where timber activities in MUSYC prescriptions were scheduled forest-wide.

Considerable discussion centered on the type of economic analysis that should be used in Forest Planning and the way costs and benefits should be portrayed in the model. In April 1979, John Sessions, economist for Timber Management, proposed the format for economic tables which were incorporated into the system.

On November 4, Johnson, Crim, and Jones[7] drafted a memorandum to Rex Hartgraves, Director of Land Management Planning suggesting

> "...an approach to resource allocation-output scheduling (RA-OS) for the accelerated planning forests that will complete their plans during 1980 and 1981. These forests were chosen in response to the President's directive to consider departure from the base timber harvest policy. Timber harvest scheduling is a significant issue on each and will form the core of their resource allocation-output scheduling problem."

The approach suggested in this memorandum had been named the Forest Planning Model (FORPLAN). The memo stated that FORPLAN includes..."MUSYC plus software linkages to various land allocation approaches that have been suggested and resource allocation matrix generators as they become available."

The memorandum became the basis for a letter addressed to Regional Foresters and National Forest System Staff Directors, and was signed on December 3, 1979, by Douglas Leisz, Associate Chief.[8] As Bill Russell described, the letter was written in response to requests that the Washington Office "make decisions on the analysis tools to be used" for forest planning. The letter directed: "The Forest Planning Model will be the required primary analysis tool for the Forest Plans." It also scheduled a technical review workshop with key Regional people for February 1980, and a user's manual and training session for FORPLAN during March.

Because the memorandum made FORPLAN the required primary analysis tool to be used in Forest Planning, further development was needed to accommodate the analytical needs of forests not included in the initial proposal.

[7]USDA Forest Service. 1979a. Memorandum from K. Norman Johnson, Sara A. Crim, and Daniel B. Jones, to Rex Hartgraves, Director of LMP. (draft mimeo). November 4.

[8]USDA Forest Service. 1979b. Letter from Douglas R. Leisz, Associate Chief, to Regional Foresters and NFS Directors. 1920: Development and use of forest planning model. December 3.

1980

A technical review workshop was held in Fort Collins in January, with representatives from the Washington Office and several Forests. It was at this meeting that the naming conventions were agreed upon (e.g. MUSYC's "timber classes" were renamed "analysis areas," and "alternatives" were renamed "prescriptions," to be more consistent with planning terminology). It was determined that "management emphasis" identifiers in prescriptions would be the allocation identifier and could not change between existing and regenerated prescriptions. Thus land allocation could not change over time. A decision also was made that analysis area acreage constraints would be set as equalities, requiring every acre to be assigned a prescription. Thus every analysis area had to have a minimum intensity prescription available so that every acre would be accounted for in the solution, but cost efficiency still could be achieved.

In February, the first attempt at modeling the one-part approach with two levels of decision variables ("aggregate emphasis") was added to the model. This feature recognized geographic areas within the forest for allocation decisions, although its application was initially very limited.[5] This addition incorporated some of the principal features contained in the Lolo National Forest model.

In fall 1980, several important improvements were made to FORPLAN:

1. Vegetative type conversion was difficult to explicitly model, so the ability was added to change from one working group in existing vegetation to another in regenerated vegetation.

2. Innovative users were augmenting FORPLAN matrices with their own to model some relationships not permitted in FORPLAN. They needed the ability to generate balance equations to serve as transfer rows for linking their matrices with FORPLAN matrices. The ability to specify constraint levels equal to zero was added to provide this capability. An example of this is a set of constraints which limits valuation of a resource to its estimated consumption level even if produced above that level.

3. Users needed a way to constrain on combinations of identifiers as a single constraint, for example, on several conifer types, as a group, to provide for minimum winter cover requirements for wildlife. "Composite" constraints were structured to provide this flexibility in constraining on combinations of identifiers. This permitted the identifiers of any number of mutually exclusive FORPLAN constraints to be combined into a single constraint.

1981

During this year the Forest Service assumed responsibility for maintenance, user support, and further development of the model from the developers.

In February, the ability to generate "free" rows was introduced. Because Version 1 never could generate more than one objective function at one time, this feature permitted any constraint to be used as the optimization criterion. It also allowed for a full set of constraints to be generated, but used selectively in later solution runs, reducing the number of times the matrix generator might be run.

In fall, the option of defining intervals spanning several time periods was added for scheduled output constraints. This had the potential to reduce the size and density of matrices by grouping time periods in these constraints. This allowed period-specific constraints in the early periods and broader interval-specific constraints over the later periods, where time resolution was not as critical.

1982

As more users began to use the system, additional needs emerged:

1. In the initial formulation of FORPLAN scheduled outputs were modeled as being dependent on the age of analysis areas or type of timber activity that was prescribed. Periodic yield types were added to permit scheduled outputs to be modeled independently from timber activity or age. This feature was an important step in improving the multi-resource capabilities of FORPLAN.

2. The President's revised Statement of Policy for the Forest and Rangeland Renewable Resources Planning Act (RPA) which was sent to Congress in January, 1980, included the policy that "the productivity of suitable forested land, in all ownerships, should be maintained and enhanced to minimize the inflationary impacts of wood product prices on the domestic economy and permit a net export of forest products by the year 2030." To help forests respond to this policy, the ability to optimize and constrain timber growth was added to FORPLAN.

3. As users became more sophisticated and management desired better ways to constrain certain activities, the types of scheduled output constraints was greatly expanded. This permitted greater flexibility and more accurate representation of the management strategies being modeled.

4. Enhancements to FORPLAN always progressed at a greater rate in the matrix generator than in the report writer. As a result, even though modeling improvements were made, it was sometimes difficult to interpret results until the report writer was enhanced. In 1982, major improvements were made in reports, including more economic reports, and more selective reporting by analysis area level identifiers.

Computer Considerations

A discussion of technical criteria in the development of FORPLAN would not be complete without some discussion of computer hardware and software.

Although FORPLAN source code was in the public domain it did not receive wide dissemination outside the Forest Service for two reasons: it was in a constant state of revision and the source code was very system-specific to Univac. The first reason is obvious when the rapid nature of the development effort is considered. The second reason is not so obvious.

Although much of the programming was done on Burroughs and Vax computers at Utah State University, modifications and production was being done on Univac at USDA Fort Collins Computer Center (FCCC). Because of Univac software limitations and the architecture of the hardware itself, many of the input/output routines and storage conventions had to be modified to reduce cost and storage requirements. This resulted in a set of code which is not easily transferable from Univac.

On January 23, 1981, Norm Johnson sent a letter to Director of Land Management Planning, Rex Hartgraves, about FORPLAN analysis costs).[9] Johnson had conducted some tests which showed that FCCC costs were 2-4 times greater than USU costs. He suggested an effort be made either to bring FCCC FORPLAN costs down or to relocate the FORPLAN use site. In response to the first suggestion, cost algorithms at FCCC were revised and efforts increased to improve the efficiency of FORPLAN on Univac. Testing FORPLAN on other sites was considered and tested on a limited basis, but the problems associated with communications and support prohibited implementation of this option.

Impacts on Fort Collins Computer Center were significant. Special procedures were required to schedule FORPLAN runs to minimize impacts on the system. This often resulted in long delays and frustrations for the users. Expansion of the computing facilities seemed to lag behind user needs.

There were a few conversions of FORPLAN to other computer systems. Conversions required a great amount of time and expense. Boise Cascade Corporation had one of the most intensive efforts and successes in conversion. Some of the applications on other computer systems are discussed elsewhere in these proceedings.

Other Considerations

Dick Field[10] played a major role in providing the goal programming feature in MUSYC and FORPLAN. His graduate work on goal programming at The University of Georgia was conducted with Timber RAM and he proposed its inclusion in MUSYC and FORPLAN. His critique led to improvements in the formulation.

Univac, vendor of the computer in use at the Fort Collins Computer Center, recognized the Forest Service as a major user of it's Functional Mathematical Programming System (FMPS) linear programming package. This is the system which solves for the optimal solution of the matrix generated by FORPLAN. Univac helped Land Management Planning to make more efficient use of the system and make enhancements which took advantage of the unique structure of FORPLAN matrices. The results were greater efficiency in solution time (reduced costs) and greater flexibility for the user.

Documentation

Formal documentation has always lagged well behind development. Although drafted in 1980 (Johnson et al. 1980), the User's Guide was not published in final version until May, 1986 (Kelly et al. 1986). Other documentation consists of an Overview (Johnson 1986), Mathematical Programmer's Guide (Kent et al. 1985), and Structures and Options Guide (Johnson and Crim 1986).

Because formal documentation was very limited and slow in being developed, the primary means of communicating with users has been through informal ways. Conference systems on the FCCC Univac, accessible by all Forest Service users, were the primary source of new information. Unfortunately, information in these conferences was not readily available to interested parties outside the Forest Service. However, final documentation cited above incorporates much of the material that was contained in these informal sources. Other informal documentation was distributed through personal networks.

Conclusion

The decision for all National Forests to use a single model as the primary analysis tool to develop Forest Land and Resource Management Plans permitted a national pool of talented and innovative people to influence development of that model. Although not explicitly referenced in this paper, many people had a role in testing and enhancing FORPLAN. Challenges they presented, innovative ideas they provided, and endless testing they conducted were an important part of the development work.

The untiring efforts of Norm Johnson, Sarah Crim, and others counted largely in the success of FORPLAN. Without such dedication and commitment, development could not have moved as quickly and effectively as it did.

Successful application of a system such as FORPLAN requires a central contact and maintenance facility. Full time, proficient help always has been available for FORPLAN users. Without such help most users would have given up in frustration or made only token use of the system.

FORPLAN Version 1 made some significant inroads in incorporating multiple resource allocation and output scheduling. It was continually expanded and modified to

[9] Utah State University. 1981. Letter from K. Norman Johnson to Rex Hartgraves, Director of LMP. Subject: Cost of FORPLAN analysis. January 23.

[10] Field, Richard C. 1979. Some comments and suggestions regarding MUSYC and goal programming. Personal communication, May 3. 7 p.

meet the analytical needs of users. Eventually, however, the basic framework of Version 1 could no longer efficiently accommodate needed changes, and efforts were channeled into a new version. The evolution of Version 2 is discussed in Reuben Weisz's paper.

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Technical Criteria Used in the Development and Implementation of Version 2 of FORPLAN

Reuben Weisz[1]

Abstract.--Version 2 of FORPLAN was designed to provide the user with flexibility in model formulation. To achieve this goal, 14 technical criteria were used to guide its development and implementation.

Dan Jones has described the development of Version 1 of FORPLAN. FORPLAN continued to evolve as its strengths and weaknesses were recognized.

An objective of FORPLAN has been to make it understandable to a wide range of audiences including people inside the Forest Service and people from other organizations and interests. FORPLAN evolved in much the same way that human understanding evolves, i.e., the evolution of understanding takes place by analogy. Each new idea is comprehended in terms of how it resembles old ideas. As old ideas are tested, the weaknesses become criteria for the growth and development of new ideas. The criteria guiding the development of Version 2 evolved from recognition of weaknesses in Version 1 and from renewed emphasis on some of the criteria used in developing Version 1.

For discussion, it is useful to divide the criteria for evolution into those that guided the evolution of the initial formulation of Version 2 and those additional criteria that also guided the evolution of later releases.

Criteria for the First Release

As we began on Version 2 of FORPLAN, there were eight criteria guiding the model development effort:

1. FORPLAN should be meaningful to our potentially affected interest groups, to line officers, and to members of the interdisciplinary teams that were most directly involved in land management planning.

If FORPLAN meets this criterion, an interested person can comprehend the input data for the model and the results produced by FORPLAN. An interested person can understand what the input and results mean for each specific land area, each specific management emphasis, and for the forest as a whole.

A major problem with Version 1 was that the procedure for developing input data was too complex for persons without extensive computer or analytical experience to understand. The outputs were scattered through many pages and a complete prescription of a given land area was difficult to assemble. If the data input procedures were less complex, those reviewing the model and its results would be less likely to be overwhelmed by them and would provide more active participation in the planning process.

2. A simple spreadsheet-like input data format should exist.

Concerns for input simplicity lead to a simple input data format called Direct Entry FORPLAN or DE FORPLAN. In contrast with the input conventions for Version 1, Directly Entered data placed all information about one prescription in one location in the data set. This made it easier to review the activities and outputs associated with a prescription. Bringing all the information together in one spot helped satisfy the first criterion--the model must be understandable.

The input format adopted for the first release closely resembled the input format used by a software package called ADVENT. Because Forest Service people had considerable experience using ADVENT in the budgeting process, the Version 2 Direct Entry format replaced what appeared in Version 1 to be a strange, new, complicated program with something resembling a familiar software package. ADVENT was the analogy needed to transform the strange into the commonplace, thus again achieving the first criterion--the model must be meaningful.

In addition, Directly Entered data simplified the analysis of spatial problems, which are addressed further in Criterion 3.

3. The model should allow different types of land organization to be represented in the analysis.

One of the major decisions to be made in planning is determining which practices or activities, and standards and guidelines are to be applied to each type of land area. Each type of land area included in FORPLAN is called an analysis area. The types of analysis that can take place in FORPLAN are in part defined by how the analysis areas are defined.

Because Version 1 evolved from the tradition of timber harvest scheduling models, it had a strata-based approach to defining analysis areas. In this approach, analysis areas

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were homogeneous, noncontiguous pieces of land; for example, "ponderosa pine, mature sawtimber, less than forty percent slopes." Homogeneous, noncontiguous analysis areas simplified the work of some resource specialists who needed to estimate yield coefficients for FORPLAN. The simplification resulted because the same type of yield, or environmental effect, could be assumed to occur on the same type of land because of the same type of management action wherever that type of land occurred. However, compiling input data for the mixed resources on a given land area became difficult because the input data were scattered throughout the data set and were not aggregated for the entire land area. Comprehending the computer printouts for a spatially contiguous land area became difficult, because the results were disjointed--i.e., scattered throughout the report.

Version 2 allows the user to enter data for (1) homogeneous, noncontiguous analysis areas; (2) heterogeneous, contiguous analysis areas; or (3) a combination of homogeneous and heterogeneous analysis areas. Some examples of a contiguous analysis area are a roadless area, a watershed, or a transportation analysis zone. The ability to provide input data for heterogeneous contiguous analysis areas is important because many planning issues are related to a specific geographic area on a forest. Managers need information to make decisions about specific contiguous areas of land.

4. The model should include all outputs, activities, yields and costs for each analysis area.

Version 1 had a limited number of activities and outputs. Besides timber, there were 10 scheduled outputs; these were either timber outputs or other outputs driven primarily by timber harvest schedules. Also, there were ten nonscheduled outputs; nonscheduled outputs tended to reflect the management emphasis or other non-changing attribute associated with a prescription. Also included in the model were eleven timber cost categories which were a function of either the acreage or output of timber harvested. While the dominance of timber concerns in the input data was logical for a model that evolved to meet the needs of timber harvest scheduling problems on significant timber forests, it made modeling nontimber activities and outputs difficult on forests (or analysis areas) where timber harvest concerns are less critical.

Version 2 allows the user to specify up to 200 activities and outputs but none of the activities and outputs are mandated. Those items tracked can be custom defined according to the needs of the analysis allowing such items as "jojoba beans" or "cave recreation visitor days" to be tracked if such outputs are relevant to resolving issues.

The ability to track a large number of items made it possible for more people interested in the land management plan to have items tracked in the model. Increased participation in the planning process occurs because the model becomes more meaningful to more people, thus again helping to satisfy the first criterion. Tracking more activities and outputs also helped attain the other criteria of Version 2 which follow.

5. FORPLAN should be compatible with the Forest Service accounting system.

The Forest Service has a standard set of naming conventions that are used to account for its activities (actions) and outputs (the results of those actions). These accounting codes are used at all levels of the organization (local, regional and national) for many types of analyses (project planning, program planning, national assessments, etc.)

Version 1 used an alternative and more limited set of naming conventions that were based on timber terminology. Such usage created problems for the users because it required a disaggregation or translation of the Version 1 conventions into the standard conventions before the data was useful. Version 2 solves this problem by allowing the user to use both standard data definitions and custom defined names, and by allowing the user to incorporate several activities and outputs into FORPLAN.

6. FORPLAN should not be biased towards a specific function of the Forest Service.

Because Version 1 had evolved from a timber management model it was best suited for analyzing the timber resource. However, the analysis of other resources was forced to take place within the conceptual framework of a timber harvest scheduling model. From a practical standpoint, the analyst and interdisciplinary team members often felt they were trying to put square pegs into round holes. Feelings of mistrust were perpetuated among those planning participants and observers who were concerned that timber activities received primary consideration during planning operations.

For example, Version 1 required at least one timber yield table in order for the model to run. This was only a minor problem in the code, but a major irritant to users having concerns with the plan's credibility.

Version 2 can be run with or without timber yield tables, because it does not force a particular functional emphasis on the model. Such operational ability makes it easier to do integrated resource analysis.

7. FORPLAN should allow costs to be expressed as a function of activities that take place on the ground.

Version 1 required that costs fall into one of two categories: (1) Timber Costs, and (2) Other Resource Costs. The latter were costs per unit of output, and the timing of the output was mostly influenced by the timber harvest schedule.

Version 2 allows the user to define costs per unit of either activity or output, and allows costs for any resource to be independent of timber activities. Costs may be defined as "cost per acre," "cost per area," "cost per mile of road," etc. This is a more straightforward and logical way of representing costs.

8. FORPLAN should not limit the number of consequences that are considered for a given resource.

Version 1 allowed 99 yield tables for each scheduled output. The yield table showed the yield per acre of a resource. Theoretically, if a forest had a hundred unique analysis areas and each analysis area had ten alternative management emphases, there could be up to 1000 (1000 = 100 * 10) unique sets of yield per acre values. However, these results had to be averaged into 99 unique yield tables.

Averaging of values could make the model less responsive to the way that alternative prescriptions would affect selected issues and concerns.

Directly Entered data in Version 2 was not limited to this restriction.

Additional Criteria for Later Releases

At first glance, the first release appeared to have everything that an analysis would require. It allowed defining the planning model in real world terms and doing so in a simple and straightforward manner. Only one problem remained. The initial release required a massive amount of input data and produced a massive amount of output. The analysis process was smothered in information. The following additional criteria were added to guide the evolution of software development.

9. FORPLAN should minimize the amount of input data required.

The first release used simple and straightforward input data procedures. However, the data sets could easily range from 200,000 to 2,500,000 records in size because of the necessity to repeat data. Therefore, this method increased the (1) costs of creating input data, (2) likelihood of undetected errors, (3) difficulty in debugging detected errors, and (4) increased the computational burden on the computer.

Later releases of Version 2 solved this problem by minimizing the amount of data that needed to be repeated by using a variety of modeling techniques such as "yield tables, yield composites, thening, coordinated allocation zones," etc. One very useful technique gave the user the ability to create multiple timing choices for the scheduling of a prescription. For a detailed description of these techniques, please see the references that are contained in the references to this paper.

As an example of how to avoid repeating data by using a relationship, consider the formula, $Y = 2X$; the value of Y equals twice the value of X.

Contrast this simple formula with a data set that contained all possible values of X and Y:

X = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, etc.
Y = 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, etc.

The simple relationships give the same information in a clear and concise manner.

Another advantage of using relationships is that they are easier to change than are the numbers that result from those relationships. Using the above example, if an interdisciplinary team examined the relationship $Y = 2X$ and determined that it should be $Y = 3X$, this would require a simple edit--changing "2" to "3." In contrast, with the first release of Version 2, one would have to change

Y = 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, etc. to
Y = 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, etc.

Using a small set of explicit relationships instead of a large data set also helped reformulate the model. Planning involves a constant need to reformulate the model to respond to changing needs for new analyses. With a data set from the first release, reformulating the model often required weeks or months of work, whereas in later releases the same effect can be accomplished in minutes.

10. FORPLAN should custom tailor the reports to meet the needs of the users.

The first release produced so much computer printout that the user was overwhelmed by information. The user's printer was often tied up in printing lengthy reports that no one had the time to read.

Later releases allowed the user to custom tailor the reports by choosing one of two methods so that only desired information was reported. This was accomplished by two means. The first was an optional reporting system in FORPLAN that allowed the user to custom tailor the reports to the needs of the analysis. The second was called the "flat file capability." The flat file is a data set containing FORPLAN results that can be downloaded from the Fort Collins Computer Center to the user's Data General minicomputer. The user could then define and custom tailor reports by utilizing the Data General "Present" report writing software.

11. FORPLAN should include a transportation analysis capability.

Version 1 of FORPLAN allowed the analysis to portray resource flows across time, especially the timber harvest scheduling problem.

Version 2 of FORPLAN also allows the analysis to represent resource flows across space; this capability is most commonly described as the "network formulation" or "transportation analysis capability." It is useful for identifying the best mix of resource projects and the corresponding best road network for a particular area. Analysts can use the transportation analysis capability to more accurately represent road costs and transportation considerations. Because road costs represent such a significant proportion of the total costs of forest management, this feature allows a better job of economic analysis to be done.

12. FORPLAN should allow the consideration of multiple outcomes in an analysis.

Models constructed using Version 1 of FORPLAN were based on an assumption of certainty. If a specific management emphasis was selected in an analysis area, then a specific sequence of timber growth and harvest scheduling events was assumed to take place. Random events which generated catastrophes or affect successional stages, such as pest infestations and the occurrence of fires, provided multiple outcomes which were either ignored or accounted for through reduced yields.

Version 2 has a "Model II" capability which allows the analysis to explicitly consider "multiple outcomes"; for example, when fire occurs, portions of stands are killed and set back to age zero while other parts continue to grow. Model II allows the analysis to more accurately depict the uncertainty associated with forest dynamics that are a consequence of random events.

13. FORPLAN should give the user the best usable information for the dollars spent on computer computations.

Early in the planning process, it became obvious that generating and solving large FORPLAN models was expensive and time consuming. An underlying criterion which guided all development and enhancement work was to make FORPLAN models as inexpensive as possible to create and solve. A variety of strategies such as "multiple objective functions, generalized upper bounds, tolerances for linear programming coefficients, scaling matrices, year groups between rotations," etc., were adopted and succeeded in reducing the cost and time involved in making FORPLAN computer runs.

14. FORPLAN should be a "white box."

This is a restatement of the first criterion; that is, FORPLAN should be understandable. It seemed necessary to restate this criterion, because the first release in some respects turned out to be a "black box" because it was not readily possible to sit down and read through a data set that contained from one-half million to 2.5 million records. The volume of records produced also reduced our ability to debug the model and to do quality control of the input data.

Later releases of FORPLAN more closely resemble a "white box." The goal of a white box is to produce a process which is easy to use and easy to understand. As FORPLAN progressed toward "white box" status, significant changes in input procedures and output results occurred.

Reducing the size of a data set by substituting shorthand relationships for the data that resulted from those relationships improved both understanding and communications among all the participants in the planning process. By explicitly displaying relationships used to generate the FORPLAN model, each user can understand how data are generated and combined with other data to form the FORPLAN model. Understanding helps quality control and the interdisciplinary process and increases participation by managers, specialists, and other interested parties.

The simplification of FORPLAN produced the ability to print out all the activities and outputs associated with one or more timing choices of any prescription. Giving the user the ability to view in one place all the yields, costs, benefits, and activities associated with a prescription allows the user to better assess whether the items that were modeled were being correctly portrayed in the model. This again helps quality control, the interdisciplinary process, and increased participation by managers, specialists, and other interested parties. Thus, as FORPLAN grew, it simplified inputting the resource data, assessing data under various circumstances, and reporting the results to the user.

Conclusions

The latest release of Version 2 of FORPLAN combines the best features of Version 1 of FORPLAN with the best features of the first release of Version 2. Many additional software techniques have been added as well. The criteria used to guide the technical evolution of Version 2 of FORPLAN resulted in a state of the art system for land management planning that satisfies analysis needs.

Version 2 gives simple and streamlined procedures for formulating meaningful FORPLAN models. The software is general and flexible enough to meet most needs for analysis that have been defined by users in this round of planning.

If one had to state one criterion which incorporates most of the other criteria discussed in this paper, it is this: **FORPLAN should allow flexibility in model formulation.** Forest planning models are ways of thinking about problems. A model is a good model if it describes the world accurately and the way the user sees it. Version 2 of FORPLAN is general and flexible enough to allow the user to view the world this way.

By meeting the criteria set out for Version 2, the developers of FORPLAN have created a product that can be used for plan development and implementation. It is hoped that in a few years, we can meet again at a workshop entitled, "FORPLAN: An Evaluation of a Forest Plan Implementation Tool."

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Evaluation of the Use of FORPLAN in Management Planning on the Shoshone National Forest

Stephen P. Mealey[1]

Abstract.--Congress' major intent for U.S. Forest Service planning was to reduce conflict and improve the quality of resource decisionmaking. The Shoshone National Forest Plan, based on FORPLAN II analysis, established management intent and disclosed effects of management at the Forest and sub-district (10,000- to 40,000-acre) levels. This approach reduced conflict, improved conflict resolution and improved the quality of decisions and management. Examples are discussed in terms of localized management intent, increased management efficiency and improved budgeting. The Shoshone's Plan reduces uncertainty and creates an improved environment for intelligent risk taking.

Reviews of the legislative histories of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) and the National Forest Management Act of 1976 (NFMA) and the resource management concerns of Senator Humphrey reveal preoccupations with conflict between members of the forestry, conservation and environmental communities. To reduce conflict and improve the quality of natural resource management decisions, Humphrey's and Congress' intent, as expressed in NFMA, was a planning process which set long- and short-term goals and objectives based on interdisciplinary team effort and a high level of public involvement.

Implementation of the Shoshone National Forest Land and Resource Management Plan began April 14, 1986. Analysis for the plan was completed in Version II of FORPLAN. Analysis areas (fig. 1) were small "contiguous, non-homogeneous" units ranging from 10,000-40,000 acres. As a result, effects of proposed actions were disclosed on a site-specific basis. More important, the plan established the Forest's management intent for the next 10 years for each of 109 geographically-distinct areas.

On June 23, 1986, a trial was held in the U.S. District Court for the State of Wyoming. Plaintiff was Park County (Wyoming) Resource Council, et. al., and defendant was the BLM with Snyder Oil Company intervener. Plaintiff sought a temporary restraining order barring the drilling of an exploratory oil well on the South Fork Shoshone River, Shoshone National Forest. They claimed, among other things, that the Environmental Assessment (EA) prepared by the Shoshone National Forest failed to consider certain alternatives and, therefore, violated the provisions of the National Environmental Policy Act (NEPA). Judge Kerr's June 25, 1986 findings, in part, follow (points of emphasis are added):

> With respect to the merits of this case, the Court finds that the federal government's review of the Snyder lease and drilling proposal was extensive. First, the **Federal Government examined the Shoshone National Forest plan** and the South Fork Oil and Gas Leasing EA, documents that had been completed within days of Snyder's filing the Application for Permit to Drill (APD) and that **discussed oil and gas operations in the very area in question.** Second, the federal government prepared a "scoping" document to outline other matters that should be considered in an additional environmental analysis it planned to prepare. That scoping statement was sent to over 300 individuals and organizations, including plaintiffs. Based on the 31 written comments received on the scoping statement, the federal government prepared an EA on the Snyder APD. That EA discussed four alternatives -- the no action alternative, approval of the proposal with stipulations, approval of an APD with an alternate road alignment, and approval of an APD with stipulations limiting activities in the fall. Based on that analysis, the federal government concluded that the proposal would not have a significant effect on the environment and issued the APD on May 30, 1986.
>
> The **Court has examined** the EA prepared for the Snyder APD and **the Shoshone National Forest plan and the South Fork oil and gas leasing EA that it incorporates.** The Court concludes that these documents fully address the matter and that the federal government's conclusion that the proposal will not significantly affect the environment is reasonable. The evidence demonstrates that **the Federal Government took the required "hard look" at the environmental consequences** of the proposal and reasonably concluded that the proposal should be approved.

During the trial I was asked by Richard Stacy, U.S. Attorney, to define my major role in the matter as

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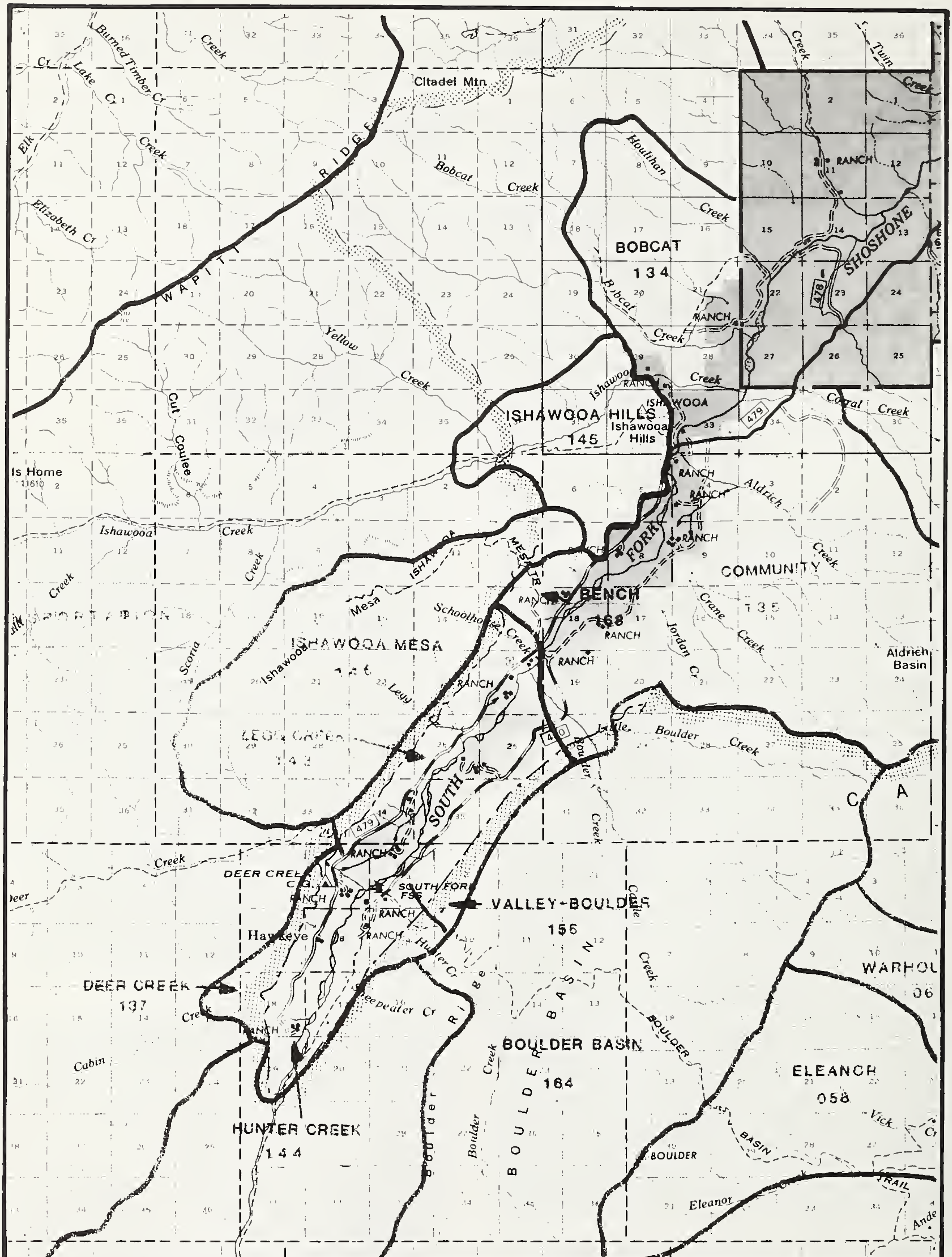

Figure 1.--Plan detail map-analysis areas, Shoshone National Forest, Land and Resource Management Plan.

Shoshone Forest Supervisor. My response: "To select an alternative from the EA prepared for the Snyder Oil APD which most closely followed the Forest's intent for the area as established in the Shoshone National Forest Plan, and recommend the appropriate action to the BLM."

Results

Judge Kerr's June 26, 1986 Decision and 6 months of informal evaluation of the implemented Shoshone Plan against Congress' expectations of forest planning, permit my belief: **The Shoshone plan has reduced conflict, improved conflict resolution, and has significantly improved the quality of decisions and management**; these trends will likely continue. This belief is supported by three examples of major results of the area-specific analysis and decision making done in Forplan II.

Localized Management Intent

Management (FORPLAN) prescriptions in the Shoshone planning model represent alternative ways of addressing issues, concerns and opportunities on small, geographically-distinct areas. The Plan represents a set of management practices selected and scheduled for each of 109 analysis areas, each area having its distinct and unique direction. Because plan development dealt with local issues on recognizable areas and the final plan states clearly the management intent in constituents' "favorite back 40s," most Forest and local issues have been resolved. A specific conflict resolution process was employed in the development of the "preferred alternative" (Appendix F, FEIS) to assure a focus on issues at both levels. A low number of Draft Plan responses (186) was interpreted to mean that the broad and local planning and issue resolution approach was effective. There were seven appeals of the Plan and five interveners. Two have been resolved, and five are pending. The legal challenge which has occurred (Park County vs BLM) was resolved swiftly and decisively because local management intent is clear in the Plan and proper tiering had occurred. Finally, because management intent in the Plan is clear at the local level, public uncertainty about future direction is reduced allowing public dialogue to shift from "what should be done" to "how to do it." The result should be better ground-level management.

Increased Management Efficiency

On July 1, 1985, Clarence Brimmer, U.S. District Court Judge for the State of Wyoming, denied a motion for a temporary restraining order sought by the Park County Resource Council to stop Marathon Oil Company from drilling an exploratory oil well on the North Fork of the Shoshone River, Shoshone National Forest. Plaintiffs contended that the Environmental Impact Statement (EIS) issued for the drill site was inadequate because it did not take into account the entire lease area, and that if the drilling were allowed, the environment would be irreparably harmed. In denying the motion, Judge Brimmer stated "especially since a thorough job was done by both the U.S. Forest Service and the BLM in issuing the drill site EIS, the Court is hard-pressed to see how plaintiffs can ultimately prove that these agencies failed to comply with NEPA."

In 1985 and 1986, the Shoshone Forest faced legal challenges from the same plaintiff over exploratory gas and oil drilling in two similar but different locations. The Court found for the Forest in both cases. However, there was a major difference. In 1985, lacking a Forest Plan, sufficient NEPA compliance required that the Forest participate in the preparation of two draft EIS's and a final EIS at a cost of $133,000. In 1986, with a Forest Plan, sufficient NEPA compliance required only a brief EA tiered to the Plan, completed at a cost of $10,000.

Efficiency in a general sense means doing more at less cost. In 1986, a completed Forest Plan meant a critical minerals management job, with National implications, could be completed adequately at 92.5% less cost than a similar job in 1985.

Improved Budgeting

Budget development often is an agonizing and time-consuming effort involving collecting data about funding needs on Districts, analyzing needs, presenting budget options and choosing among options. Ideally this involves a complete analysis of each project in terms of financial benefits and costs, multiple-use benefits and costs and environmental, social and economic impacts. Information is reviewed for all projects, and a budget is developed that meets constrained budget levels and maximizes net public benefits. Before Forest Plans, this ideal was rarely achieved, primarily because necessary information on projects was lacking and a suitable mechanism for competitively examining all possible projects was unavailable.

On the Shoshone National Forest, as shown, FORPLAN II was used in a site-specific manner. One of the features of FORPLAN II is that the full set of report information can be translated onto a form compatible with the decision-based software on the Data General (DG) computers. This means that much of the information necessary for analysis of potential projects is readily accessible through use of generalized report writers and programs, such as Spread Sheet.

The level of analysis done as part of Forest Planning on the Shoshone, when combined with accessibility of information, answers many of the difficult questions involved in budget development. The mix of projects and intents necessary for maximizing net public benefit is complete. Information on practices to be applied by distinct geographic areas is available. This information, when meshed with tentative budget levels, is ready for analysis and decision making. The important result is an efficiently-developed budget directly linked to and accurately reflecting the intent of a site-specific plan.

Conclusion

In most situations, an inverse relationship between risk and uncertainty is apparent. That is, low risks seem appropriate when uncertainty is high, while greater risks seem appropriate when uncertainty is reduced. In today's management climate, with increased issue complexity and reduced budgets and staff, managers are encouraged to accept greater risks in management and decision making. Intelligent risk taking can occur only when the degree of uncertainty is known. The Shoshone's Plan, with analysis and management direction at both Forest and local levels, reduces uncertainty about management intent and creates an improved environment for intelligent risk taking.

Use of FORPLAN in Management Planning on National Forests

Orville Daniels[1]

Abstract.--Managers and decisionmakers encounter new management challenges when using complex planning models. They must assemble an analysis team made up of unfamiliar skills, manage the process carefully, and be prepared to use the results appropriately. Managed well, such models can be a positive decision tool.

The Forest Service has just completed a massive 6-year use of the planning model, FORPLAN. While the advantages and disadvantages of FORPLAN modeling for resource land management decisionmaking are being debated and explored by professional planners, little attention is being given to the management implications. The past 6 years have shown that few general managers are trained or experienced in organizing for, directing, and interpreting complex optimization modeling. The purpose of this paper is to explore management concepts for the manager who has decided to incorporate modeling into their decisionmaking process.

FORPLAN use to plan for large land masses is costly and requires much management attention. These costs include computer time, staff salary, and delay in the decision process. You can expect that starting with data base formulation and moving through to a legally supported conclusion may take more than 1 year and cost about $200,000. Also, considering the potential for serious mistakes means that the manager should not start the process if he or she is unwilling to devote the resources and attention to do it well.

First, most units will need to create an analysis team which will increase the size or alter the makeup of the organization. Operations research, economics, and Forest planning skills, and a team of resource specialists, will be needed. It is essential that they be at or above the journeyman level. Skimping can be disastrous. Seldom does operations research and economic skills encompassed in the same person work as well as with two people. Generally it is better to have part-time separate skills rather than combine them. The synergism is worth the cost, and there is normally not enough time available for one person to do the job. The bottom line is a core team of well trained, experienced, technical people supported by a wider pool of resource specialists.

Second, with the team in place, a management climate and atmosphere must be established. This too is very important. Creativity, curiosity, and identification with the mission of the planning effort is critical. Choosing people who display these characteristics is important, as is maintaining a climate in which these attributes are encouraged. Use your best management skills to develop trust and personal responsibility. Establish that this is a staff function being done for you, the decisionmaker. Show its importance by your involvement, by expressing your management needs and vision, and by taking the results seriously. Early demonstration maximizes payoffs. On our Forest, we eliminated timber sales from our program early in analysis because of indicated problems. The team was strongly motivated by that display of the importance of their work.

The manager should be willing to devote considerable personal time to the process. Your involvement not only motivates the team, but constant involvement reduces committee compromises. Compromises by the team are not as acceptable as a decision by the manager after the team has done the trade-off analysis. At one point, our team was considering solutions where sensitivity analysis showed $1,000/AUM shadow price for elk and we directed them back to a less costly solution. Keeping track of such items calls for periodic briefings and accessibility. The team knew they could contact me at any time to resolve problems. It was also important to be available at critical times during the analysis, even if that was Saturday morning.

Managers need not understand the details, but should understand the concepts being used to handle the major resource issues. Issues such as sediment production, timber growth and yield, and wildlife cover needs are often greatly affected by the methods used in modeling. The manager should know and control which methods are used. After all, the model must be consistent with the manager's view of the world. If not, one or the other must change.

There are some pitfalls possible, including coefficient development, the black box syndrome, and impatience.

Coefficient development, such as timber yield tables, unit costs, and resource coefficients, are the foundation of the model. Give your people as much time and encouragement as possible to do this job well. Some of your people may have to spend considerable time updating themselves in their profession before they ever start with the coefficients. Encourage it. We found that the confidence people had in the coefficients made them strong ambassadors for the plan during implementation.

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The black box syndrome is a fear, suspicion, and overdependence on the machine. A good analysis team should be able, after a little experience, to fully explain the results of model runs and predict outcomes of various proposed changes between runs. When this ability is developed, the black box syndrome begins to dissipate and eventually the whole team can develop a more 3 realistic expectation from the model. Be aware that a manager can add to the black box syndrome by his or her own fear, suspicion, or overdependence. Instead, ask questions and mentally compare results with what you know about the land. Learn the key variables and know what is not quantified in the model. In other words, give leadership to the analysis.

Impatience is natural in this process, but needs to be curbed. This is a complex, large, and new process. Accept that things will not go as smoothly as planned and that errors will be made regardless of how hard people try. If a hard punishing accountability approach is followed, creativity, curiosity, and risk taking will suffer; the product will be diminished, and the schedules are likely to be missed. Or worse, errors may exist that are not found by your team, but surface after you have published your results. Try to help the team solve problems, rather than add to stress by a witch hunt. They already will be stressed by the delays if you have helped them be committed.

A fourth pitfall is a lack of vision or understanding of how you will implement, monitor, and evaluate the final plan. By having a clear vision of these three steps, you can give better leadership to the planning process and aid the analysis team through the details. You may have to constantly remind people of the product resulting from the planning effort.

The use of FORPLAN may sound too difficult to manage. I hope not. It is a challenge, but not an excessive one, and the results are well worth the effort.

Panelist Discussion of FORPLAN Evaluation Papers: Session I

D. L. DeAngelis[1]

Abstract.--This discussion considers a few basic issues involved with FORPLAN for the point of view of its adequacy as a model framework. These issues are (1) the optimization approach, (2) linearity of models, (3) spatial resolution, and (4) uncertainty.

My comments are those of an outsider to management and planning modeling, but one who has worked in mathematical and computer simulation modeling for the past 15 years. I believe that an outsider without preconceptions can bring some useful perspectives to reviewing FORPLAN.

As a modeler who focuses primarily on the basic research aspects of ecological systems, in reading and hearing the papers presented on FORPLAN I was impressed that the development and use of management models is as intellectually challenging a problem as that of developing and using more research-oriented models.

The scientific and management aspects of our interest in ecological systems are not greatly different. Underlying our study of these systems is a desire to make them work better to serve our needs and, also preserve certain intrinsic values in such systems. The use of mathematical models is a way to help achieve these ends.

In these comments, rather than reviewing individually the papers on the agenda in Session I, I will try to address some of the main issues involving the adequacy of FORPLAN as I see them. A major point I wish to make is that the creators and users of FORPLAN are dealing with some of the same problems and concerns that modelers in the ecological sciences are encountering. For this reason, I want to make a bit of a digression to outline my subjective view of the connections between management models and research models.

Research Models and Management Models

I am using the term "research model" in a somewhat restricted way to refer to models used mainly for scientific rather than management ends. This is an oversimplification, because management models such as FORPLAN can be used both in a research mode and for planning.

Models normally used in research might be classified into three general categories: (1) descriptive models, (2) heuristic models, and (3) predictive models. Descriptive models merely try to fit some sort of mathematical relationship to observed behavior. Regression models fitted to data points are of this type. Heuristic models are attempts to explain or understand a phenomenon by describing it in terms of more basic mechanisms. For example, the Lotka-Volterra equations are a heuristic model that attempts to explain oscillatory behavior of biological populations. Predictive models are designed to forecast future behavior of a system. (A predictive model may be very good at prediction without being based on a correct understanding of the system, as the Ptolemaic model of the planetary motion exemplifies.)

Most models used by research ecologists are mixtures of descriptive, heuristic, and predictive aspects, rather than being purely of one type. However, I would estimate that heuristic and descriptive aspects dominate over predictive aspects in most ecological models. Some ecologists are unhappy over this state of affairs. Peters (1980) has stated that "the making and testing of predictions is the necessary and sufficient condition for all science." He asserted that ecology will not become a "mature" science (in the sense that physics is, for example) until a predictive body of developed. I believe that limited predictive capability is present in some areas of ecology, but accurate prediction is still a far-off goal.

A final comment about research models is that operationally, if they deal with dynamic systems they usually employ differential or difference equations or some variations of these.

How do management models relate to research models? Because they are used to project the possible future results of alternative management strategies, they are similar to predictive research models. A management model must incorporate some form of predictive model. This may be in the form of explicit differential or difference equations, or it may be implicit, through the derivation of model coefficients by other, predictive models. However, management models such as FORPLAN also differ from research models in important ways, because they contain two additional components:

1. An objective function, which measures something the management program is trying to optimize;

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2. Constraints, which limit the allowable behaviors of the system based on human decisions.

It is in the addition of these two components that management models such as FORPLAN diverge from models used in research. Because of this management models have to be judged, in part at least, by different criteria than research models. The objective function and constraints embody economic and societal values, the evaluation of which is outside the range of science.

Aside from the objective function and constraints, however, the management model is a predictive model. It simply turns around the question, "What will happen to the system under certain conditions?" to, "How do we impose a strategy of activities to get the system to behave in the best way for our needs?" Thus, models for the management of natural resources must rely ultimately on predictive models from biology and ecology.

As stated earlier, the present capacity of ecological models to make predictions is generally low. This necessarily imposes limitations on the effectiveness of management models that rely on ecological information. I am sure that users of FORPLAN are aware of this, but I believe the problem of predictive uncertainty in ecological systems needs reiteration.

One point of this digression has been to call attention to the close relationship of research and management modeling, and it leads to the corollaries that the users of natural resource management models must be well acquainted with the state-of-the-art in ecological research modeling and that research ecologists can make a contribution towards improving the ecological components of management models. Another point has been to stress the uncertainty in most current models. In the next section, I will discuss the problem of uncertainty in more detail, along with three other issues that I think are important to discuss in relation to FORPLAN.

Some General Issues Related to the FORPLAN Model

There are four general issues concerning the FORPLAN modeling approach that seem important ones to me. These issues all relate to the applicability of this approach to complex ecological systems. I will first list these issues and then discuss them separately:

1. The use of economic optimization models in dealing with ecological criteria;

2. The linear structure of the FORPLAN approach;

3. The degree of spatial resolution in FORPLAN;

4. The uncertainties in model parameters going into FORPLAN.

Issue 1. Optimization

The approach taken is to combine decision variables additively into an objective function, which is then optimized. The creates problems, as is well-known, because market and non-market values have to be combined; that is, values such as wilderness and habitat preservation have to be expressed in the same currency as timber and grazing values. If this currency is in dollars, as it seems to be almost always in FORPLAN, the latter values are likely to overwhelm the former ones.

It is true that environmental values can be safeguarded by applying appropriate constraints, which FORPLAN has special flexibility in doing because of its spatial explicitness (discussed below). Still, the utilitarian bias implicit in the optimization approach seems to ensure that the intrinsic values such as species diversity and landscape aesthetics will get less emphasis. These values may be maintained, but not optimized.

One possible alternative approach would be to develop another economic objective function besides the type now used, one based purely on ecological values. These functions could be optimized separately and then a "bargaining" process between the advocates of the utilitarian objective function and the advocates of the ecological objective function could be undertaken. A particular objective function might combine species diversity, the welfare of certain selected species, and some landscape factors. There are ways of quantitatively ranking such values in importance through methods such as the analytic hierarchy approach (Saaty 1980). This quantitative ordering could be used to construct an ecological objective function. Environmental advocacy groups could be invited to do this.

Issue 2. Linear Model Structure

FORPLAN is a linear programming approach, which means that the objective function and constraints are linear functions of the decision variables. In principle, the coefficients of the objective function and constraints can be computed even if the underlying predictive model describing a dynamic system is nonlinear. However, this is only an accurate approximation if the nonlinearity is mild enough to allow piece-wise linearization.

There has been a history of debate in ecology about whether linear models are able to describe ecological systems in an approximate way. However, today very few ecologists would deny that ecological systems are nonlinear. These systems are characterized by sharp jumps in variable values (e.g., population levels) at thresholds, rather than continuous behavior. For example, a portion of habitat (or archipelago of habitat islands) of a given size may be able to support a sizable population of a particular species, but if the size is made only slightly smaller, it is possible that no population will be maintained. This sort of phenomenon, related to mathematical catastrophe theory, is common in highly nonlinear ecological systems.

For these reasons, when criteria such as the maintenance of certain wildlife populations are required, there is some question about how reliable linear models are. It may be that clever use of constraint inequalities can get around this problem to some extent in FORPLAN, but this will require the use of detailed population models as input

to FORPLAN to estimate what the constraints must be to maintain species populations.

Issue 3. Level of Spatial Resolution

The types of options that can be included in an optimization model depend on, among other things, the level of spatial resolution in the model. In this respect, there has been considerable progress over the years in the development of FORPLAN.

It may be interesting to compare some trends in ecological theory with similar trends occurring during the same time period in National Forest model development. Early models of interacting ecological populations, such as the Lotka-Volterra equations, ignored spatial extent and heterogeneity. In the early 1970s, theoretical ecologists (e.g., Horn and MacArthur 1972) attempted to deal with landscape heterogeneities by considering the landscape to consist of fractions of different landscape types, each of which could be occupied to some fractional extent by different species. Explicit spatial relations between portions of habitat were not included. Starting in about the middle 1970s, with work by Levin (1974) and others, a further elaboration on the inclusion of spatial characteristics was begun. These models reflected the view that relative spatial positions of habitat areas of various types are important, not just the fractions of the landscape covered by the types.

With explicit spatial models of ecological systems, theoretical ecologists can study both the spatial dynamics of ecological communities, and the temporal dynamics. Important aspects of spatial dynamics include such things as faunal dispersal, the persistence of populations on sets of noncontiguous habitat patches, and the spread of pests and other disturbances.

In the models leading up to FORPLAN, there has been a similar type of progression from very simple models that ignore space to those in which spatial aspects are explicit and detailed. In particular, the steps from Timber RAM to FORPLAN involve, in simple terms, the following spatial properties.

1. Timber RAM. This is a harvesting model with a specified number of timber classes. Although these timber classes refer implicitly to areas of land, no spatial heterogeneity or explicit spatial relationships are included in the model.

2. MUSYC. This model approach allows, among other things, a variety of treatment types, with constraints on area or volume treated by a particular treatment type. Thus, there is spatial heterogeneity, though the explicit spatial patterning of this heterogeneity is not incorporated in the model.

3. FORPLAN. Explicit spatial heterogeneity and geographic location are incorporated in the model by defining a set of zones.

I do not think the degree of spatial resolution in FORPLAN is capable at this point of dealing with many of the important ecological spatial aspects mentioned earlier. However, in a gross sense, FORPLAN permits the recognition of landscape heterogeneity and makes it possible to treat land areas with high significance to wildlife in a special way. There is potential for increased spatial application in the future if necessary.

Issue 4. Uncertainty

As mentioned earlier in this paper, uncertainty is present in all ecological systems, whether managed or not. Even if all initial conditions in such a system could be measured perfectly, unpredictable random disturbances, such as unusual weather, fires, or pest outbreaks, can occur. These produce uncertainty even in well understood relations such as timber yield functions, but can produce enormous uncertainties in other biological components of ecosystems. This is because effects of disturbances are often amplified in ecological systems. Besides being subjected to random disturbances, ecosystems can also undergo long-term continuous changes caused by slow changes in exogenous parameters such as climate or by cumulative effects of human-caused influences such as acidic deposition.

The consequences of this uncertainty in system behavior is that the coefficients of the objective function and constraints in FORPLAN are necessarily highly uncertain. The FORPLAN approach, however, is deterministic. Only the means of the coefficients are included in the analysis, not the variances, which would be large if known. The problem with this is that the analysis will compute only the most likely outcome of a particular management strategy, not the risk of undesirable outcomes.

My feeling is that the structure of FORPLAN allows the inclusion of uncertainty, but only with difficulty. It should be mentioned that there are other management optimization models that include uncertainty, though these models are much smaller than FORPLAN models. An example is a model for the reduction of phosphorus loading to a lake (Bogardi et al. 1981). In this model several alternative measures are considered that may be taken to reduce P loading, each of which would cost a certain amount of money and have a certain expected effect. Besides the mean expected effect of each measure, the variance was also included in the model, reflecting the uncertainty inherent in the efficacy of the measure due to random effects. The results of the model are expressed in terms of a probability distribution of possible total effects on P loading for the best strategy, so that both the risk and the likely result of poor performance can be seen.

Given the large size of most FORPLAN models, I doubt that the uncertainty can easily be handled in any thorough manner in the fashion of the above example. The variances of hundreds of parameters would have to be known, and A Monte Carlo simulation of absolutely gigantic proportions would have to be carried out. Nonetheless, it may be feasible to do some sensitivity analysis on a small set of parameters that are perceived to be crucial. For example, the probability of satisfying a particular ecological constraint, such as the maintenance of an endangered species population, could be computed in relation to an optimal strategy by including uncertainties in species

dynamic behavior. If the risk to the population under this strategy is perceived to be too high, a suboptimal strategy that reduces the risk might be preferred.

I believe that the FORPLAN approach should have the capacity to select suboptimal strategies when they sufficiently reduce the risk of an undesirable outcome. I suspect that in actual practice, this sort of mode of FORPLAN usage is already possible to some degree. Mealy (these proceedings) reported that FORPLAN has helped avoid high risks by recognizing situations with high uncertainty in outcomes.

I have commented only on uncertainty arising from the general impossibility to predict accurately the behavior of ecological systems. There are other sources of uncertainty, simply because, in models of any kind, there can be a variety of types of error, including programming and simple transcription and typing errors in preparing input information. All modelers who have worked at their trade for very long have at some point reached the sobering realization that big models inevitably contain errors. The size of FORPLAN models makes it difficult to do enough experimental runs to ferret out errors of this sort. It is advisable that techniques be used to minimize the probability of error occurrence.

Conclusions

In summary, it is difficult not to be highly impressed with the quality of thought that has gone into the FORPLAN approach and with the excellence of the personnel involved in developing and using it. It is easy to point to some of FORPLAN's problems and limitations, as I have done, but any other approach would have as many or more difficulties. Also, I like the idea of there being a single modeling structure, such as FORPLAN, rather than a chaos of different approaches for each administrative unit. Despite the effort required to understand it, the net effect of FORPLAN seems to be to focus thinking and promote communication. Given the flexibility of the FORPLAN framework, and the ingenuity of its users, I believe that most of the issues I have raised (and probably other issues as well) can be dealt with adequately.

My comments are intended to be constructive. Some are doubtless naive and cover well-worn ground, but I believe they may represent those of an outsider who has had only a few weeks to become familiar with FORPLAN. I hope that, as such, these comments will be helpful in the evaluation of FORPLAN.

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Reflections on the Development of FORPLAN

K. Norman Johnson[1]

Abstract.--The Forest Planning Model (FORPLAN) is discussed in terms of its uses in national forest planning, why it remains a mystery to people inside and outside the Forest Service, and its role in completing the national forest plans. Predictions are made about future developments in the forest planning methodology and suggestions are made about the limits of analysis in solving forest planning problems.

The Need for FORPLAN

FORPLAN has gained a significant role in national forest planning for three reasons:

1. It was available when the national forests wanted a forest planning model, and it deals with the two major themes that have been at the center of forest planning: (a) the scheduling of timber harvests within constraints, and (b) the pursuit of cost effectiveness.
2. It helped break the hold of professional omnipotence on national forest management planning.
3. It helps shield the Forest Service from attacks by its critics.

Being at the Right Place at the Right Time

National forests primarily build roads and cut timber. Most national forest planning has addressed timber management and road management scheduling. Therefore, the National Forest Management Act (NFMA) addresses the control of these action more than any others. The Act is very one-sided in its treatment; almost all the attention is focused on timber management scheduling.

It is not surprising that the national forests turned to a model that has its roots in timber management scheduling. As documented by Iverson and Alston (1986), FORPLAN descended from a long line of timber management scheduling models.

Models may appear to be abstract and sterile calculation procedures; but they really are embodiments of the philosophy and ways of thinking about problems of the people who build them. FORPLAN is no different.

To foresters, the heart of forestry is the birth, growth, and death of trees, stands and forests. Further, to foresters, the important issues in forest planning relate to active manipulation of the forest, and such planning should focus on what timber harvest levels can be sustained over time, given the objectives and constraints from all forest uses. FORPLAN reflects this orientation in its long time horizon, long planning periods within this horizon, and use of vegetation age and rotation length as organizing principles that focus on issues across time instead of space. Such an orientation is compatible with the emphasis in NFMA, but takes the focus on traditional forestry perspectives far beyond their emphasis in that Act.

Economists are interested in objective-oriented problem formulations, the finding of efficient solutions, and the related perspective of finding a maximum or minimum subject to constraints. FORPLAN also reflects this orientation with its optimization (linear programming) approach to problem solution, use of a present net worth objective function, and focus on delineation of a wide range of choice. It is more difficult to find justification for this economic approach in NFMA than the focus on timber management. While the Act mentions that efficiency should be considered, it is not emphasized. A much stronger focus is the assurance of protection of the forest environment during all actions.

Selection of an optimization model for forest planning has limited the ability to consider environmental effects in detail in forest planning modeling. I do not believe that an optimization model such as FORPLAN is required by the NFMA. An equally strong argument can be made for models that emphasized the simulation of environmental effects from road building and timber harvesting. Some "efficiency" might be given up; but the ability to estimate environmental effects might be increased.

The focus on optimization models resulted from three separate threads of development that became intertwined: (1) my continued development of timber scheduling models based on the work of Daniel Navon, who introduced harvest scheduling with linear programming to the national forests (Navon, 1971); (2) the fascination of land management planning with linear programming as expressed through the development of the Resource Capability System (Betters 1978); and (3) the focus of the Committee of Scientists, under the leadership of Dennis Teeguarden, on economic efficiency and trade-off analysis.

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To my knowledge, a comprehensive evaluation of optimization vs. simulation models never occurred before the selection of FORPLAN as the primary analysis tool, despite the importance of that decision. By default, the national forests chose the pursuit of economic efficiency in their forest planning model over the detailed simulation of environmental effects, with much of that simulation either left to secondary models, or left out.

With the rewrite of the regulations in 1982, the fusion of timber management scheduling and economic optimization became complete. In fact, the regulations now read, in large part, like the work of a Ph.D. student in forest economics. The "greatest good for the greatest number in the long run has been recast as "net public benefit." Benchmarks that require maximums and minimums have been added and economic terminology has been inserted whenever plain English appears about to surface.

Whatever the process of legitimization and development, forest planning as we know it and FORPLAN appear inseparable. It is true that FORPLAN was built to serve forest planning, and also that the national forests use FORPLAN's capabilities and limitations to mold and defend what is done in forest planning. The claim that "FORPLAN cannot handle it" has become a well-worn reason for not representing an aspect of forest planning of interest to someone.

Even the public must deal with FORPLAN. Continual references to it occur in presentations of Forest Service personnel and in draft forest plans. Also, constructing a comprehensive alternative to a proposed forest plan requires that the information be processed through FORPLAN. To many people, FORPLAN symbolizes forest planning more than any other aspect of the planning process.

Quantitative Analysis as Protection Against Professional Omnipotence

My Ph.D. thesis focused on the evaluation of alternatives for a roadless area in the Coast Range of Oregon. Although it was light on quantitative analysis, it did build a simple harvest scheduling model to simulate the harvest of the Siuslaw National Forest, with and without the timber from the roadless area. Out of this thesis have come the two major interests in my professional life: (1) the multiple-use, sustained yield problem on national forest lands; and (2) timber management scheduling as the heart of forest planning.

My first major modeling effort occurred in the context of an analysis of future timber availability from Oregon's forest lands that culminated in the "Beuter Report" (Beuter et al. 1976). Lynn Scheurman and I built the TREES model to do the projections on timber availability, with Lynn handling the mechanics of model building and I providing the ideas on what it was to accomplish. That model has had a long life. It and its progeny, such as TRIM (Tedder 1986) are still in wide use.

About that time John Walker began pushing his ECHO model at the national forests (Walker 1976). We had put the ECHO option into the TREES model, and Region 6's Timber Management staff asked me to use it in a study on national forest timber harvest levels.

In that analysis, I looked at national forest scheduling results based on Timber RAM and noticed some peculiarities that RAM was causing. Over about 2 months, I built a harvest scheduling system that overcame these difficulties and presented the results to a collection of National Forest System personnel in Portland. Using these results as a springboard, I began to work with the National Forest System build a model, called MUSYC, to replace Timber RAM.

After completing MUSYC, I returned to policy analysis. However, the Roadless Area-Intensive Management Study (Fight et al. 1979) brought me back to modeling. Using the Willamette National Forest's own planning model (a traditional timber management planning model), we showed the Forest that the harvest level could be maintained without accessing the roadless areas by intensive timber management on the accessible land. Forest personnel were unimpressed. They said that their planning model ignored so many constraints from resource objectives besides timber that the model did not accurately reflect the benefits and costs of different timber management plans. Rather, they substituted their own qualitative judgment for the model results to a significant degree.

While no model completely reflects reality, their forest planning model was so far off as to be largely irrelevant. They had used it to understand better how much timber management investment would be needed to maintain the harvest, but were not interested in its results beyond that.

If the Forest did not believe its own forest planning model, it would be of little use for policy analysis. This triggered the search for a model that could incorporate constraints and objectives for resources beyond timber production, and led to the building of both FORPLAN Version 1 and FORPLAN Version 2.

In one sense that search has succeeded too well. Now the Willamette N.F. must use the exact allowable sale quantity (ASQ) from the FORPLAN run for the preferred alternative as the ASQ in the Forest Plan. Constraints and objectives from other resources now must be represented in the forest planning model to have an effect on ASQ. While the result helps surface the assumptions of the planners, it is still a source of concern that it drives out the intuitive and nonquantifiable aspects of this analysis.

Planning models are valuable to planners and decision-makers to the degree that they allow these people to think through their problems. These are not predictive models of what will happen in the future. The data is too scant for that. Rather, they organize the objectives, constraints and assumptions of the people using the model to help them understand the implications of their proposals--to help them answer the what-if questions as they search for solutions to planning problems. These models are not meant to dominate the process or drive out aspects of the thinking by planners or decision-makers that cannot be quantified.

Such reliance on models shows a lack of faith in the judgment of resource professionals. Lack of trust in the Forest Service by outside interest groups and citizens has led to more demands for justification for each action. This,

in turn, has led to the demand for "objective" analysis, which seems to result in quantitative analysis.

FORPLAN fills that need. It is one tool in an internal cleansing of the professional beliefs and tenets that have guided national forest management from its inception. It is part of the attempt to prevent professional groups within the Forest Service, especially foresters, from imposing their objectives for management of the forest on the rest of society. But in the process, the qualitative judgment of resource professionals may be lost.

Protecting the Forest Service from its Enemies

FORPLAN also is a formidable roadblock to gaining leverage to push the national forests in any direction other than the one they wish to go. The complexity and subtleties of its options, the comprehensiveness of its view, the incredibly ambitious task given to it by the national forests, and the tremendous variance in its use from forest to forest makes it difficult to understand it and its use.

Yet, analytical attempts to disagree with the national forests must often deal with it. Few outside the Forest Service have figured out how to do that. Without the knowledge of FORTRAN's intricacies, fear exists that (1) those on the outside will not understand the key analytical pressure points that control the solution and, therefore, will not know what are the key assumptions behind the harvest levels; and (2) even if they could figure out the key assumptions, the national forests could reconstrain the model to obtain the same answer.

Thus FORPLAN is very effective at preserving local agency discretion. It represents a formidable way for the national forests to insulate themselves from their critics.

Why Is FORPLAN Such A Mystery?

FORPLAN remains almost as much a mystery to most people in the Forest Service as 8 years ago. It certainly remains a mystery to people outside the Forest Service.

I have outlined below six reasons for this phenomenon: (1) FORPLAN's inherent complexity, (2) lack of publication about it in scientific journals, (3) lack of in-depth analysis of its results, (4) separation of the people with forest planning problems from people analyzing these problems, (5) the counter-intuitive way FORPLAN represents problems, and (6) lack of the model's availability to outsiders. Also, I suggest some remedial action.

First, FORPLAN remains a mystery because of its inherent complexity. Starting with the Committee of Scientists and going right on through to the building of FORPLAN, we have developed a forest planning process that may go beyond the average planning team's ability to implement. Involvement of university scientists in forest planning has enabled these faculty to try out their ideas on planning in the largest field laboratory ever utilized--the National Forest System. Combined with the Forest Service's can-do attitude, the work of these scientists may have resulted in a planning procedure beyond the ability of ordinary people to complete successfully.

Although we tried to write FORPLAN so that it would be understandable to potential users we may have misjudged our clients. We probably wrote it for the most analytically sophisticated of the planning teams rather than the average. This orientation, combined with the mobility of Forest Service employees, has meant that the average planning team may feel befuddled by FORPLAN.

Second, FORPLAN remains a mystery because its methodologies and use have not been published in the scientific literature. The development of national forest planning methodologies has proceeded outside the organized research community. New ideas were developed and directly implemented in national forest planning without the publication and peer review basic to the research process. The aggregate emphasis-coordinated allocation approach to forest planning is an example. This approach is used throughout Region 6; yet, it has never appeared in the scientific literature.

The National Forest System does not encourage publication of findings by its people, in contrast to the Forest Service Research branch. Publication takes time and energy away from other activities. Thus, much of FORPLAN and its procedures is passed along among managers and planners. In all the criticism I have heard of FORPLAN within the National Forest System, lack of publication in the scientific literature has not been one of the complaints.

Third, FORPLAN is a mystery because many of its practitioners don't understand it. Traveling to the national forests around Oregon and around the country, it is discouraging to see how little time is spent understanding why particular FORPLAN results are being found on each forest.

Certainly the "benchmark analysis" added to the revision of the regulations in 1982 ensures that at least a mechanical set of trade-off analysis will be done. The numbers from these results also can lend themselves to being summed to regional totals. But this approach to developing the choices also drives out creative analysis by focusing on a set number of runs.

Planning teams could do more FORPLAN analysis than the benchmarks; but there is rarely any time for that. Reliance on the creativity of the analyst, which had some successes and some failures, often has given way to lock-step mediocrity. A "FORPLAN analysis" now often means doing a benchmark run and surfacing a few summary numbers. Digging into the details of the results to understand "why" things are happening occurs less often.

The long time between the analysis and plan release compounds the problem. The person who did the analysis often is not on the job anymore.

FORPLAN training also has contributed to seeing forest planning as a mechanical procedure. The training sessions have been concentrated on organizing the input and creating the output needed to do a FORPLAN analysis. They have focused on what the options are and what the reports mean. They have not concentrated on how to integrate the information produced by FORPLAN to understand the key factors determining the results. Without this understanding, though, we remain outsiders seeing changes happening from run to run without understanding why.

Fourth, FORPLAN remains a mystery because of the separation of analysis from the people who needed it to solve their problems. Good planning models are extensions of the thinking of the people for whom they are intended. With the addition of the "operations research analyst" as the specialist on the planning team, we have created a position for a professional modeler. The advantages of this approach are that the analysis can be done more quickly and in a more sophisticated fashion. The disadvantage is that no one besides the "analyst" may know how they are representing their forest planning problems in FORPLAN. Thus the forest supervisor and forest planner, who often have to meet with the public to discuss FORPLAN results, may have no clear idea about the forest planning model that is producing the results they are trying to defend.

Fifth, FORPLAN remains a mystery because it represents forest planning problems in ways that run counter to how people think about these problems. Timber management scheduling, with its emphasis on assessing biological sustainability over long periods using homogeneous response units may be second nature to a forester but foreign to other resource specialists. Beyond that, many people find it difficult to plan the forest as a whole, compared with planning for each acre or stand individually. The notion that a forest-wide constraint requires that an acre be managed for some use or at some intensity for the greater good of the entire forest remains unsettling to people.

Sixth, FORPLAN remains a mystery to most people because the model itself remains physically inaccessible to outsiders. Interest groups and academics have provided technical oversight of Forest Service planning in the past; but FORPLAN has not proven very transportable to sites and machines beyond the USDA Fort Collins Computer Center. Thus, the model itself is still not readily available for outside testing and analysis.

Increasing Our Knowledge About FORPLAN

Some steps can still be taken to make FORPLAN less mysterious:

1. Reports on the model structures and use of FORPLAN in national forest planning should be published in the (peer reviewed) scientific literature. Because the National Forest System generally will not do this, work by academics or Forest Service Research personnel will be needed. The recent FORPLAN documentation (Johnson 1986, Johnson et al. 1986), and sessions such as this help somewhat; but they do not substitute for peer-reviewed publication.

2. The latest releases of the FORPLAN model should be made transportable to other sites and types of computers. Toward this end, we at Oregon State are developing an IBM PC-AT[2] form of the latest release of FORPLAN Version 2. Although the PC version will not be able to solve the bigger forest planning models, it could be an extremely valuable teaching and research tool.

3. The national forests need to provide a mechanism for their own people to improve their understanding of how to identify the key factors controlling the FORPLAN analysis, as the objectives and constraints are varied.

[2]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Is the FORPLAN Game Over?--The Oregon Experience

For the past 5 years in Oregon, the national forests have been trying to put forest planning and FORPLAN analysis behind them. From repeated announcements of overly optimistic release dates of forest plans, to making completion of the forest plans a critical element in the evaluation of forest supervisors' performance, the Forest Service has been trying to finish the forest plans. However, forest planning is still with us, and probably will be for at least 2 or 3 more years in Oregon.

Forest plans for 3 of Oregon's 13 national forests have been released, and the remaining plans are scheduled for release within the next 6 months. Over 8 years and tens of millions of dollars in the making, these plans hold the key to Oregon's timber-based economy to the year 2000. First indications are that the plans will propose a 20% decline from current timber sales and harvest.

After release of the draft plans, the public has 3 months to comment on the most sophisticated planning effort in natural resources ever attempted in the history of the world. I believe that Oregonians and their governmental officials will need more time to understand these plans.

We in Oregon need more understanding of what the national forests are proposing and why. We need outside review of the technical merit of the underlying assumptions in the plans. And we need to understand the likely timber harvest from other owners. Especially projecting the likely harvest from private industry lands is important in western Oregon. Yet, the inventory information needed for these projections will not be available until early 1987.

The FORPLAN analysis is crucial to increasing the understanding of Oregonians as to what the national forests are proposing and whether it has merit. We need a full airing of the data, assumptions, and philosophy behind the FORPLAN models used in the proposed forest plans. Also, additional FORPLAN analyses undoubtedly will be required to test ideas on the key factors controlling the harvest, and to test proposals for new alternatives that emerge from involvement of the citizens of Oregon and other people from around the country.

At a recent meeting of the American Bar Association, James Torrance, Regional Forester in Region 6, pointed out two general sources of potential public dissatisfaction with the proposed forest plans: (1) lack of understanding of what is being proposed, and (2) different beliefs (values) as to how the forest should be used. He did not point out one other potential source of public dissatisfaction: incomplete, uncreative, and perhaps even shoddy analysis by the

national forests in development of the forest plans. Yet many of the current complaints about the forest plans fall into this third area.

Understanding the quality and completeness of the forest planning analysis will take time, as will the development of information about likely harvests from private landowners in Oregon.

Forest Planning Methodology--Where Is It Headed?

I finish my talk by making some observations and predictions about the future of forest planning methodology:

1. The uncertain future of integrated planning,
2. Difficulties and potential developments in FORPLAN-like models pertaining to considering budget restrictions, ensuring representation of effective prescriptions, and recognizing the multiple outcome nature of actions,
3. The shift from strategic to tactical planning,
4. The virtue of building future forest plans from the ground up, and
5. The role of FORPLAN in finishing the forest plans under construction.

Does Integrated Planning Have a Future?

In 1981, I predicted that a "revolution" would occur in forest planning models as they changed from traditional timber harvest scheduling models reflecting the perspective of timber management to integrated resource planning models reflecting the perspectives of a multitude of resource specialties simultaneously (Johnson 1981). achieving such a multiple resource perspective was difficult. A major impetus behind Version 2 of FORPLAN was the attempt to provide that multiple perspective, or at least to allow the user to choose the particular resource perspective to emphasize.

Maintaining an integrated planning approach requires constant effort. Centrifugal forces in the Forest Service continually threaten to pull apart the cooperation between the resource specialties that form the basis of such integration. Tradition, the budgeting process, training in the resource schools, and the professional subcultures that cut across natural resource organizations all work to divide planning along functional lines.

Land Management Planning has had the responsibility to ensure that no one broke ranks during forest planning; but it remains to be seen whether forest planning has brought a permanent change in the philosophy of planning in the Forest Service. It is still an open question whether the spirit and letter of integrated planning will be transferred down to the District level during plan implementation and up to the Washington office during output target and budget selection.

Considering Budget Realities in FORPLAN

The role of budget constraints in shaping forest plans has never been clear to me. Budgets have traditionally been ignored in long-run forest planning. Rather, the national forests have concentrated on selecting politically acceptable output levels with the belief that the budgets to support that those levels would be forthcoming. Many of the preferred alternatives require a higher budget than currently available, and few of the forest plans present alternatives under somewhat reduced budgets.

Many FORPLAN models probably reflect this lack of concern for budgets, in that they do not have management choices under each emphasis that reflect the possible range of investment and operating cost. Applying a budget constraint in such a case will result in the model finding an inefficient solution in the sense of reducing output or changing the land allocation more than needed. Faced with such difficulties, I worry that budget reductions will cause the national forests to abandon their forest planning models, and the tremendous amount of work they represent, and return to the old rules-of-thumb in deciding what to do.

Finding Efficient Solutions

The problem is one of ensuring that efficient prescriptions for the management of an area are included in the FORPLAN model. This problem is especially difficult, because the most "efficient" prescriptions depend on the objectives and constraints of the particular alternative.

Most of the focus on constraints has dealt with the explicit right-hand sides that appear in the linear programs created by FORPLAN. Much less effort has been spent on the constraints implicit in the prescriptions recognized in the linear program for management of an area. Yet, these latter constraints can have as large an effect on the solution as the explicit right-hand sides. And they do not produce a trail of shadow prices that can help highlight their importance.

Some of the outside review of forest plans in Oregon and elsewhere will concentrate on whether the national forests have introduced arbitrary constraints into their models through the choices that are represented. Future advances in forest planning also are likely to include breakthroughs in this area.

Recognizing the Multiple Outcome Nature of Forest Actions

Despite the great uncertainty surrounding forest management, foresters have traditionally assumed that they had a perfect vision of the effect of their actions and of the future value of their outputs. FORPLAN represents this perspective through the allowance of only one outcome associated with each action or event.

In FORPLAN, investing in a timber stand or a recreation area does not produce a multitude of outcomes

with different probabilities, but rather a single outcome with a probability of 1.0. The natural growth of some timber stands does not show a portion of the acres dying each decade, but rather steady aging through the planning periods. Over the next 10 years, I expect to see the recognition of multiple outcomes in forest planning. That work has begun with the recent efforts by Tom Stuart and me (1984), and Reed and Enrico (1985).

From Strategic to Tactical Planning

As forest planning moves from setting land allocations and output targets to implementing these results for the first decade, strategic planning models will gradually fade out of the picture. Linear programming-based models, such as FORPLAN, are useful for setting broad guidelines for management of the forest through time, but are much less useful for the project planning across space that accompanies plan implementation.

A new class of models is arising for short-term spatial analysis based on network optimization instead of mathematical programming. Emphasizing road management scheduling and project selection, these models will focus on finding efficient strategies for plan implementation, given output targets and detailed spatial constraints for particular areas on the forest.

These models will be the focus of attention within 5 years as the controversy over the use of public land switches from what should be the land allocation and output targets for each forest to what actions should occur on each drainage and plot of ground. By explicitly representing spatial considerations, such as clearcut size restrictions (adjacency constraints), these models can more accurately reflect the realities of project selection.

Building Forest Plans from the Ground Up: Salvation or Folly?

The results from this analysis could, in turn, become the basic building blocks for the next set of forest plans just as the forest plans are, in theory, the building blocks for the Resources Planning Act assessment and program. Building the forest planning choices from the ground up would allow for more accurate representation of the spatial considerations, such as the stand-adjacency constraints, than possible in current forest planning efforts.

Such a suggestion has been made during this planning effort and is discussed in the FORPLAN Version 2 Overview (Johnson et al. 1986). However, except for some forests that are creating packaged choices for critical areas on the forest for the few planning periods, little use has been made of the approach.

Dividing the forest into watersheds for forest planning and representing the alternatives for each watershed through spatially feasible package choices describing a set of actions over time for these areas is a fine objective. No one should suppose, though, that it will simplify forest planning.

Developing choices for watersheds while recognizing the actual distribution of stands in each area, ensuring that the necessary range of choice exists to enable efficient forest-wide solutions, and reflecting all the environmental constraints on potential actions is a formidable task.

Forest planning has always been hamstrung by its attempts to make programmatic statements about effects that are aggregations of individual actions on the forest over time, without actually representing the actions in the planning models measuring the effects. Doing in-depth analyses of the feasible actions on individual areas and then representing packages of these actions through time as choices in a forest-wide planning model would bring together the measurement of environmental effects and the actions underlying them.

But there is a drawback to this approach. Barber (1986) rails against the continual introduction of complexity and detail into forest planning. Yet, the proposal I have outlined here, and have often made in other contexts, does just that.

If forest planning has taken more than a temporary aberration in the direction of quantitative planning, then the agency must face the widening gulf between the people doing this analysis and the people whose problems the analysis is set up to solve.

We are close to that situation now on some national forests. Models that cannot be explained are not progress. Models so complicated and costly to check that they are beyond inside and outside review have no place in public land management.

The time is long overdue for the Forest Service and its outside critics to begin to suggest the sideboards over complexity and sophistication that will be allowed on models that deal with the important issues in management of the national forests.

FORPLAN's Role in Finishing the Forest Plans

Turning the problems that now exist with forest planning models over to operations research technicians and systems analysts for repair will probably result in more complex and sophisticated models. That approach may help future planning efforts, but will not help finish the forest plans.

Rather, we need to learn how to use the analysis that has been created so far to define the choices available for management of the national forests and to use models such as FORPLAN creatively to search for new alternatives that better integrate the interests of the competing factions in national forest planning.

The national forests may have worn themselves out in preparation of the draft plans, and outside groups and institutions may need to take a stronger role in helping to complete the forest plans. I believe outside oversight will be needed to ensure that a fair and high quality cumulative economic effects analysis is done.

Involvement of these traditional constituencies, however, is not enough to complete the forest plans in a state such as Oregon. We also will need the formation of broadly-based citizen groups working with the Forest Service, perhaps through professional mediators, to find

areas of common agreement and to suggest alternatives to the Forest Service proposals, where needed, that more satisfactorily mesh their interests.

Especially in Oregon, where almost all issues revolve around the allowable sale quality, the FORPLAN analysis has a potentially significant role to play. Both in terms of the need for people to know what key factors control the harvest, and in providing an assessment of what any proposal means in terms of ASQ, FORPLAN has a continuing function.

Until now, FORPLAN's major function has been to help forest planning teams evaluate the implications of each forest planning alternative. The real challenge of the FORPLAN work in the near future is to make it useful in the next phase of forest planning when outside groups and individuals have a larger role. The FORPLAN analysis is not over--it has just gained a new set of clients.

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Session II:

Experience in the Implementation of FORPLAN by Industry and State and Provincial Governments.

FORPLAN in the University: Berkeley's Experience

Lawrence S. Davis[1]

Abstract.--Six requirements are identified to successfully install and sustain the use of FORPLAN in a university environment. The most critical is the need for faculty expertise to efficiently teach the use of FORPLAN. Forest management research is classified by three attributes: (1) aggregation level of analysis, (2) source of data, and (3) kind of research. FORPLAN is ideally suited to empirical analysis at the ownership level of aggregation.

It's worth saying again for the record that the national forest planning problem has to be the most complex we've ever attempted to model and analyze using linear programming. In its purely analytical dimensions the problem's multiple goals, multiple outputs, multiple decision makers and multiple planning periods for heterogeneous land tracts of 1 million acres lets us easily conceive of linear program matrices with more than 1 million columns and 20,000 rows. Reality forces us to compromise on less, at least for now, and there is real concern that present models already may be too large.

All this multiplicity doesn't even consider the political and legal dimensions of public lands that regularly alter both the rules of planning and the objectives and constraints of the planning problem. Al Dyer once gave me the rules for the TINKERTOY[2] game where small groups of people are given a standard box of tinkertoys and told in statements written on the blackboard to "build the highest free-standing structure possible under three rules: (1) there are 20 minutes to plan, (2) 40 seconds to build, and (3) no pre-fitting of parts while planning." I've used the game 15 or so times and its now abundantly clear that many people have a hard time understanding these simple planning instructions. They often build feasible, well engineered, sturdy structures no higher than 6 inches that a truck could drive over. The rules, alas, did not ask that the structure support a truck, but only that it stand long enough to be measured. I occasionally illustrate national forest planning in this game context by waiting until there are about 2 minutes left to plan and then loudly scream that" you can no longer use the blue sticks, no more than four of the orange connectors, and only three people in the group can physically participate in the building." The result of this last minute change is usually anger, dissension in the groups, and some quitting the game.

Fortunately in class we have an option not available in the real world -- to relent and proceed with the original game. After terrorizing the student planners it prompts good discussion about how the planning problem can change faster than we can model it. Land owners and decision makers always will have ever-changing goals, constraints, and problem solving procedures and rules do get politicized in the real world.

Dealing with such complex and dynamically changing problems requires powerful, flexible, and easily revised analytical aids and problem data. I think the FORPLAN matrix generator and report writer was forged in such an environment and has developed to be such an aid. It's now time for it to spin off from its USFS home to let the academic, private and other public agency communities concerned with long-term land resource planning problems use and expand its power. There are many challenging and exciting FORPLAN applications beyond national forest planning: macro level problems of state resource planning, integrating federal and state planning, national level resource planning in developing countries, industrial application, and micro planning at the small private forest owner or village agroforestry systems level.

As a fellow traveler on the fringes of FORPLAN development, I watched its development from MUSYC through release 10 of FORPLAN 2. Most of this was at Utah State University working with Norm Johnson, Kim Marshall and the dozen or so students caught up in the heady excitement of forest planning. I finally escaped my department head chores and moved to Berkeley in 1982 where I'm now trying to recapture normal life as a forest management professor. I always had thought FORPLAN had great potential as a forest management research tool; and finally I have my chance.

This paper reports a case study of one academic's initial successes and failures in transplanting FORPLAN to a university and building a research program around it. I report from the viewpoint of one who uses FORPLAN but has to rely on others for technical support. I have few numbers to report, because none of the studies are finished. However, I'll (1) describe what seem to be the minimum resource requirements needed to successfully support and use FORPLAN at a university, (2) discuss the kinds of research for which FORPLAN is particularly well suited,

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and (3) briefly describe the research problems and applications we have underway at Berkeley.

INSTALLATION AND SUPPORT REQUIREMENTS

If you are anything like me, when you open the shipping box and look at the 9-track tape labeled FORPLAN, an overwhelming reality hits that you have no Fort Collins Computer Center (FCCC), no handy Norm Johnsons, Tom Stuarts, Kim Marshalls, or Jim Kellys, you are not a programmer, and you have limited skills with the campus mainframe operating system. In short, you are truly on your own. If you can get past the urge to mail the tape back, then you have to make the commitment to build your own support system and stand independent of the Forest Service. A local support system has the following important elements.

1. A mainframe computer with adequate disk, tape, and cpu capacity, a large and well-supported linear programming package, and, it is hoped, a bargain rate schedule.

At Berkeley we're blessed with a trouble-free, souped up IBM[2] 3081 that has a good rate schedule. The only potential issue is the computer center's rising reluctance to pay the support cost of MPSX as campus overhead. Surprisingly, only a few people on campus are working with large scale linear programs, and the computer center may try to charge the $15,000 annual support cost against us few users. If MUSYC and FORPLAN move to the PC-AT[2] as rumored, then this requirement may be more easily satisfied, particularly for matrix generation and running small test, teaching, and research problems.

2. Operating system support staff who understand the operating characteristics of FORPLAN and can write a menu-type executable or job control language which assigns, opens, and closes files, lets you easily implement one of a dozen or so packages of execution runs, provides comprehensible error messages, and keeps track of costs.

After several false starts I discovered Al Stangenberger who has developed as a master of the mainframe CMS operating system. We obtained the IBM[2] converted version of FORPLAN II, release 4 from FCCC and struggled to get it compiled. A new FORTRAN compiler helped and by the time we received a copy of FORPLAN II release 10 it went up quickly and is fully converted to FORTRAN 77.

At the critical installation point, we hired Kim Marshall from Logan to consult for two days and he and Al roughed out the operating system control package. Al has subsequently refined it and prepared help menus to the point where I can understand and comfortably execute runs. Release 10 with the source and object codes, the CMS executable, OS job control language, and the Tom Stuart problem sets is what we have been sending people who want to try FORPLAN themselves on the IBM.[2]

3. Teaching program in modeling forest management planning problems, including instructors and courses to teach students, research technicians, and interested faculty the many conceptual and mathematical structure options for building linear models of forest planning decision problems. Supporting courses in mathematical programming, operations research, economics, business, and policy also are needed.

At Berkeley I do this teaching. My senior and graduate forest management courses appear adequate to get the students started and we have excellent support in the disciplinary departments. I've been doing most of my research work with graduate students and, to state the obvious, a university has to offer graduate programs in forest management and economics if good students are to be attracted and the research program is to be sustainable.

4. Continuing capability to teach FORPLAN including the many option for preparation of problem data and files, understanding how these files relate to the many different conceptual and mathematical problem formulations possible, understanding the users manual, interpreting error messages, effectively debugging problem files, and guided practice from simple through complex formulations.

I am finding this to be the most difficult requirement to satisfy. I sat through some of the initial FORPLAN short courses at Logan but my real personal training came when Tom Stuart kindly came to Berkeley and put on a very intensive 3-day training program for about 15 students and faculty. We mainly went through the set of staged problems he built to illustrate FORPLAN's capabilities. The copious notes and scribbles on my computer printout "textbook" is my primary reference to this day.

I have copies of his problems and used them last fall to teach my graduate class how to use the system. The students also modified a simple timber management problem file, executed a few runs and interpreted the results. But, like most of you, I have to do other things. When returning to FORPLAN after a 6-month vacation from its details and then trying to help a student debug a problem, I find it isn't so easy to remember all those symbols and rules or exactly how coordinated scheduling works.

I've about decided that not only must I maintain a research program using FORPLAN, I must regularly build files and use the system to keep up a skill level needed to teach and transfer the technology to a continuously changing group of students and other users. I think it's critical that at least one regular faculty person commit to FORPLAN as a primary skill area and the center of research, outreach, and consulting for a long time. Otherwise you or the university could be in the embarrassing fix of having put up FORPLAN but nobody remembers how to use it.

5. Access to high-level consultation to resolve difficult problems and errors and to determine if the cause is your file preparation or the code itself.

The few times I needed such service I leaned on old friends. However, I can envision more frequent needs as we start new and different problem formulations that break little known or untested rule combinations. One way or another, such high level consulting is needed by new and occasional users. If the Forest Service cannot regularly provide this service for free, maybe they could charge for the consultation? Perhaps we non-USFS users could help ourselves by establishing a users group and identifying the people to network with.

6. Money to implement items 1-5. This takes an institution or grantors willing and able to invest in people

Table 1.--A multi-attribute classification of management and planning research

Attribute I: AGGREGATION LEVEL OF ANALYSIS

A. Stand and stand type questions and problems
B. Forest or ownership level policy, decision and implementation problems
C. Multiple ownership regional, state, and national level resource allocation. supply and policy problems

Attribute II: SOURCE OF DATA

A. You borrow data sets developed by others
B. You create original data sets

Attribute III: KINDS OF RESEARCH

A. Conceptual and developmental studies
   1. Pure theory and model derivation
   2. Tricks and techniques to formulate new or difficult problems for solution by existing models and algorithms
   3. Demonstration of theories and techniques on simplified or hypothetical data bases
   4. Creating new analytical tools and software.

B. Empirical Analysis and Hypothesis Testing

   1. Sensitivity analysis and hypothesis testing to understand the effect of input data, problem formulation strategies, or stochastic properties of model coefficients.
   2. Policy, planning, and decision analysis. Manipulating problem variables under control of decision makers to quantitatively estimate benefits, costs, and implications. Creating alternative problem formulations to reflect different decision-maker viewpoints.
   3. Validated experiments comparing model results with the measured reality of historical records or forward looking longitudinal studies and monitoring data.

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and pay the computer charges while a program is developing, the users are learning their trade, and data bases are being established. After you get started and pay some dues, grandiose plans for many new data bases and extensive analysis roll forth. Then, more money is needed.

FORPLAN'S ROLE IN THE GROVES OF ACADEME

To justify the considerable investment required to establish a FORPLAN based research program, program benefits need to be identifiable and substantial. For private companies or consultants, the benefits are increased profits from selling better company services, reducing costs, or improved resource allocation efficiency. Seth Peters of Boise will give us glimpse of the private company application and perhaps some of the consulting companies putting the system up may want to comment from that perspective.

At the university benefits are measured by teaching, research, and extension results and for the individual professor, the primary benefits are necessarily publications that lead to fame, fortune, and tenure. This paper takes the university research perspective and dwells primarily on how FORPLAN could fit into a forest management, economics, and policy research program. First I'll present a classification of management and planning research and then relate it to FORPLAN to discuss possibilities and limitations. The classification shown in table 1 organizes research questions and projects by three attributes affecting the problem size, data needs, tools and cost of such research. I'll avoid the temptation to classify our management economics literature in this framework and look at it as a new researcher implementing FORPLAN as a research tool.

Management and Planning Research: Classification and Development

Research costs and computational complexity increase with shifts from stand to forest to multi-forest aggregation levels and with shifts from conceptual to empirical studies. Costs can markedly increase when original data sets are constructed by the researcher. Its not surprising therefore that much of the early literature of forest economics and management focused on theoretical and empirical study of stand level questions such as "what is the optimal rotation and cultural schedule." Such work was directly based on economic theory, computationally satisfying, and the empirical data was not prohibitively expensive. The early financial maturity analyses of Duerr and the many current

papers using dynamic programming are good examples of this research.

When computers and linear programming became available, we finally could deal effectively with forest or ownership level questions and quantitatively evaluate harvest schedules, questions of harvest flow policy, and investment in intensive management. When timber RAM and some of the binary search simulators developed to handle large problems and several western national forests created reasonably accurate data bases, then we could finally estimate the empirical import of the allowable cut effect (ACE) and related harvest policy questions. Several studies used many different forest data bases for policy analysis of old growth disposition and to refine the operational definition and meaning of sustained yield.

Research Opportunities for FORPLAN

An era of serious empirical multiple use tradeoff research has just now arrived stimulated largely by the current round of national forest planning that mandated consideration of empirical and value tradeoffs between all forest outputs. Our traditional preoccupation with timber production and timber policy research concurrently is giving way to examination of these much more complicated spatially, temporally, vertically and horizontally linked multiple output production problems. These are the problems FORPLAN is designed for: multiple-use empirical research at the firm or enterprise level in terms of the classification, research fitting attributes **I-B, II-A,-B,** and **III-B-1,-2,-3** are the central domain of direct FORPLAN research applications (the creation of FORPLAN itself would be a **III-A-4** study).

A classic study of the **III-B-3** type applied to multiple forest data sets was the roadless area tradeoff study by Randall et. al. (1979). Many administrative studies conducted by the NFS are of this type such as the commercial thinning study headed by Sarah Crim (1983) in Region 6 and the statewide cumulative effect study underway in Idaho and those starting in Oregon and California.

For the university the most expensive aspect FORPLAN research can be obtaining full scale data sets. Borrowing data sets is an obvious way to keep costs down; but our current options are limited to borrowing national forest data sets.

These are large data sets developed at a cost far greater than what nearly any university could afford. However, then we must work with national forest lands and accept as given their land stratifications, prescriptions and much of the basic yield and management response data. To seriously rework the files would require that we also have the maps and much of the source data used by the forests. The forests may not want or be able to supply all the data we want, nor be willing to pay for their analysts and managers to spend enough time educating the academic about the problem formulation details and rationale such as, "Why are the constraints were set this way?" or "Who supplied the various subjective coefficients?" There still are many opportunities for sensitivity and aggregate policy analysis research using NFS data sets, and I'd expect to see considerable research of this type. It might be profitable for us to discuss how the USFS, the universities, and affected parties could be more effective partners in this effort.

Creation of new data bases carefully designed to examine specified research questions will surely be the heartfelt desire of any serious forest management researcher. Original mapping and inventory is expensive, especially if you want accuracy sufficient for convincing ground truth validation. Many times you will want to re-stratify the land base, say to look at different allocation zones or different ways to model wildlife habitat, and this requires a reasonably high resolution spatial data base and a geographic information systems to use it. Timber inventory plot records have to be located spatially or be identified by enough strata labels or bio-physical land attributes that they can be sorted and regrouped to match the chosen land strata. Another aspect of data base development is that it's slow business. It could take 3 to 5 years to finish a data base ready for research use--dangerous strategy for the untenured professor.

Some universities have a well-documented management-oriented research forest and most of the needed primary data is already available. This source provides the first independent data base we are building at Berkeley. We have also recently organized the California Forestry Research Cooperators which includes Industrial, State, Federal, and University members. We have a management/economics project and hope to use this as a means to build several data sets.

It would be good, for example, to use several representative private land data bases in FORPLAN as a sample of the state to empirically evaluate the impact on the private landowners of proposed state forestry regulations and other policies. I'm also persuaded that FORPLAN could be a useful and effective tool for planning, managing, and doing management research on small properties of 2,000 to 10,000 acres. The trick here would be to pre-package a large menu of identifiers (particularly timber condition classes), prescriptions, yield files, and economic data sets for the general forest area in question. Then for an individual owner problem all that would be entered is the owner's unique analysis areas, goals, and constraints.

A third kind of data set is the fake and half-fake forest. Fake or artificially generated inventory and growth data for many different stand and land types can be used to create artificial forests by attaching different acreage to these stand types. For spatial assessment these types also could be assigned to the mapped cover type polygons of a real but uninteresting or uninventoried forest. The half-fake forest would use real inventory data to define stand types but the acres assigned to each stand or stand type is chosen for research purposes. While fake forests are not samples of reality, they are inexpensive and effective data bases for some sensitivity analysis and some kinds of policy analysis studies. What they cannot do is support aggregate quantitative estimates of policy implications.

CURRENT FORPLAN APPLICATIONS AT BERKELEY

We now use FORPLAN for two well-defined research applications, and two more are in the works. Also, it has been used in teaching and may possibly be used for consulting. These projects and activities are as follows:

Forest Management at Blodgett Forest Research Station.

Our main studies started with creating a high-resolution data base for our 3,000-acre research forest located at 4,000 feet in the mixed conifer type of the Sierra west slope. The data base consists of detailed maps and more than 1,000 permanent inventory plots. The maps are of timber cover type detailed by height in meters, percent crown cover at three heights, and total percent crown cover, slope, elevation, aspect, soil type, roads and stream (by types), plus the contiguous units of watersheds and management compartments. An understory cover map detailed by species, height and density is being prepared. This spatial data base has been digitized and exists as 1/4 hectare grid cell data base in our SPANMAP geographic information system.

A special data layer in the grid data base contains the identification number of 1,000 permanent inventory plots by the grid cell in which they occur. This allows us to intersect and stratify the land in many ways and produce a list of plots that fall in each strata. This plot list is then used to organized the plot records in a R5000 data base, push them through the CACTOS growth and yield simulator, average all plots in a strata, and produce yield files directly in FORPLAN format. A couple of clever students, Peter Daugherty and Mark Jamnick, developed the software and procedures to do this labor saving file manipulation work on the PC.

We plan to make the data base dynamic by updating the vegetation cover type map every year and saving each year as a data layer. This will allow detailed longitudinal tracking of cutting patterns and the associated wildlife and range habitats, edges, clumps, corridors, visual character, and other issues related to spatial dynamics. This should enable us to do some work on the vexing problem of linking planning to implementation on the ground and to help refine the meaning of "spatial feasibility."

This data base has taken 3 years to put together, and we think it will allow us to efficiently develop FORPLAN data bases for many different problems and research questions. The biggest limitation of Blodgett as an empirical data base is that it is all excellent site and grows trees like mad. To model a more typical forest with site II and III land, we will have to obtain the yield data elsewhere and artificially lower the site of some compartments in the models. Much of the Blodgett data already existed and some of the hardware and software was free or being built for other projects. However, it still cost us about $15,000 in direct costs plus my time and some time by the permanent staff at the forest. If you had to create a comparable data base from scratch and pay all the costs, it probably would be between $50,000 and $100,000 for a 3,000-acre tract. Three studies are now using this data base.

Effect of Alternative Land Classification on Calculated Forest Outputs

The first is looking at the effect on even-aged harvest schedules of strata based vs. area based land classification at several different levels of classification resolution each. This sensitivity study will be run on several different starting forest inventory structures. This project is Mark Jamnick's dissertation work and should be completed within a year.

One of the more difficult issues is how to make meaningful comparisons between harvest schedules, because almost every different formulation implies a different goal or constraint set. For example, if area based models are used then this generally implies that there are some spatial constraints in the problem modeled--else why use compartments? It would seem that to fairly compare yields and outputs from a contiguous but heterogeneous area-defined problem to a homogeneous strata-defined problem requires that the spatial constraints implicit in the area formulation are comparably imposed on the strata model.

Conditions Favoring Even- vs. Uneven-aged Management Systems

The second study is using the basic data developed by Jamnick and adding a large number of single tree selection uneven-aged prescriptions plus some small group selection uneven-aged prescriptions. The small (1- to 3-acre) harvest areas of small group selection are themselves even-aged but may have different yield properties because of competition with adjacent older adjacent stands. Collectively a well designed dynamic mosaic of small cuts may be able to emulate visual and other qualities of single tree selection. We want to explore the differences between even-aged, uneven-aged, and small-group selection management at the forest or ownership level and to identify the range of goal, constraint, species, initial forest structure, yields, price and cost conditions that cause movement of prescription choices between these management systems.

Management of Small Forests: Blodgett as a Case Study

The third study is management of Blodgett itself. We need to set up a long-term operational plan for the forest to guide our actual harvesting and cultural program. Blodgett makes most of its operating income from timber sales. The current cut is about two million board feet and this is about our estimated LTSY. Our objective is to maximize the first period net income subject to non-declining undiscounted net income and subject to a myriad of spatial constraints related to research programs and also integer controls to require cutting an entire even-aged compartment whenever it is entered. The applied research question here is "how well can FORPLAN handle this sort of a problem and can gains in efficiency be found for properties as small as 3,000 acres that more than cover all costs of using FORPLAN?"

The California Forest and Rangeland Assessment Program

A second major application of FORPLAN is to integrate data and organize the reports for the simulation model used to estimate alternative future trends in ownership, use, activities, and outputs from California's public and private forests and rangelands. In concept and substance this state-level assessment is much like the RPA assessment required of the Forest Service.

We have built a simulator called CALPLAN (Davis et. al. 1986) that models the non-Forest Service lands of the state by stratifying the land by county, cover type, owner, and owner objective (which we call "owner behavior class"). Alternative futures are modeled as changes in the distribution of area by cover type, owner, and owner behavior. Who owns the land and what they are likely to use it for drives this simulation. These changes are subjectively projected by expert opinion based on interpretation of past trends, county planning, possible state policy and various assumptions about demographics and the state's economy. The simulator has many elements (fig. 1). We also have taken the final step, and view the program purely as a simulator, prompted mainly by the lack of a meaningful aggregate objective function for private lands in the State. We skip the idea of optimization entirely and directly simulate a linear programming solution file as the output of the model. The solution consists of an allocation of current land types, ownership and behavior (analysis areas) to future owner/behavior classes (prescriptions). The FORPLAN report writer picks up the hardwired solution plus all the activities, outputs, costs, and yields associated with these strata and prescriptions in the yield and problem files, and writes out a report. We have tested this procedure with small- to medium-scale problems, and it works. I expect that computer will be relatively low, because we have skipped the matrix generator and the LP solution costs.

The solution for the state's private lands will contain about 150,000 non-zero variables and the report writer will summarize on more than 100 activities and outputs at various levels of aggregation. Robin Marose has put together all the software to run CALPLAN and stripped and changed a copy of the FORPLAN code to efficiently serve purely as a report writer on this simplified but large scale problem.

The Forest Service lands are modeled by including the preferred plan of each national forest and its associated outputs as a column in our solution file. As best we can (the documentation and facts are scarce) we're including the current plan and level of output from all other public ownerships as additional columns.

As a post-CALPLAN/FORPLAN extension, we are simultaneously considering all Forest Service plan alternatives along with multiple options for private lands. The private land options are modeled by different CALPLAN scenarios driven by different state policy assumptions about investments, regulations, etc. This menu of all public and private choices will allow some regionalized sub-state and state-wide analysis of cumulative effects and can help define the range of collective choices for integrated federal state resource planning. Some preliminary runs suggest that the current national forest planning alternatives are not well designed to illuminate possible between-forest or forest-to-private tradeoffs, that many alternatives are infeasible at current budget levels, and that the independent forest-at-a-time schedule for review and comment precludes substantive state level input.

Other Applications of FORPLAN

Two additional projects that make use of FORPLAN are in the formation stage. The first is an outgrowth of the Blodgett application and will more extensively test the applicability and efficiency gains from sophisticated analysis of small private forest properties. The forest management cooperative program with forest products companies in California has three sequential projects. The first is to build an economic stand evaluator to couple with growth and yield models.

The second project is to semi-automate a linear programming analysis of the short-term (5- to 10-year) scheduling of sales or purchases of stumpage with financial objectives and under constraints over time on cash flow, species mixes, etc. This model will use the stand evaluator model to prepare the column data for each stumpage sale option.

The final project will go to long-term planning, where it may be possible to effectively use FORPLAN. We are making the yield and economic data for the stand evaluator and sale scheduler compatible with the input formats of this data in FORPLAN.

For a different application altogether, I have students in the undergraduate class make LP models of a village agroforestry system. Sometimes these hand-entered problems run to 3,000 columns and 500 row matrices which we solve with a combination of LINDO and MPSX. One graduate student took this another step and managed to replicate such a problem in FORPLAN. Because the agroforestry problem simultaneously considers a combination of a land allocation and crop production problem, a nutrition problem, a population growth problem, a crop and labor import-export problem, and a competitive market problem, the students typically make a hundred or so runs to test and do sensitivity analysis on many possible variables. The question to explore is can we speed this up with FORPLAN and make use of the report writer to eliminate much of the tedious hand processing of results.

SUMMARY

FORPLAN unquestionably has great potential as an analytical research aid to investigate important and interesting management and policy questions at the forest or enterprise level. This will not be easy or cheap research, because high resolution, large scale data bases must be built or borrowed to characterize realistic forest ownerships. For the larger state and national level policy questions, each ownership is but one observation -a sample of the land base- and several such forest data sets are needed to give a

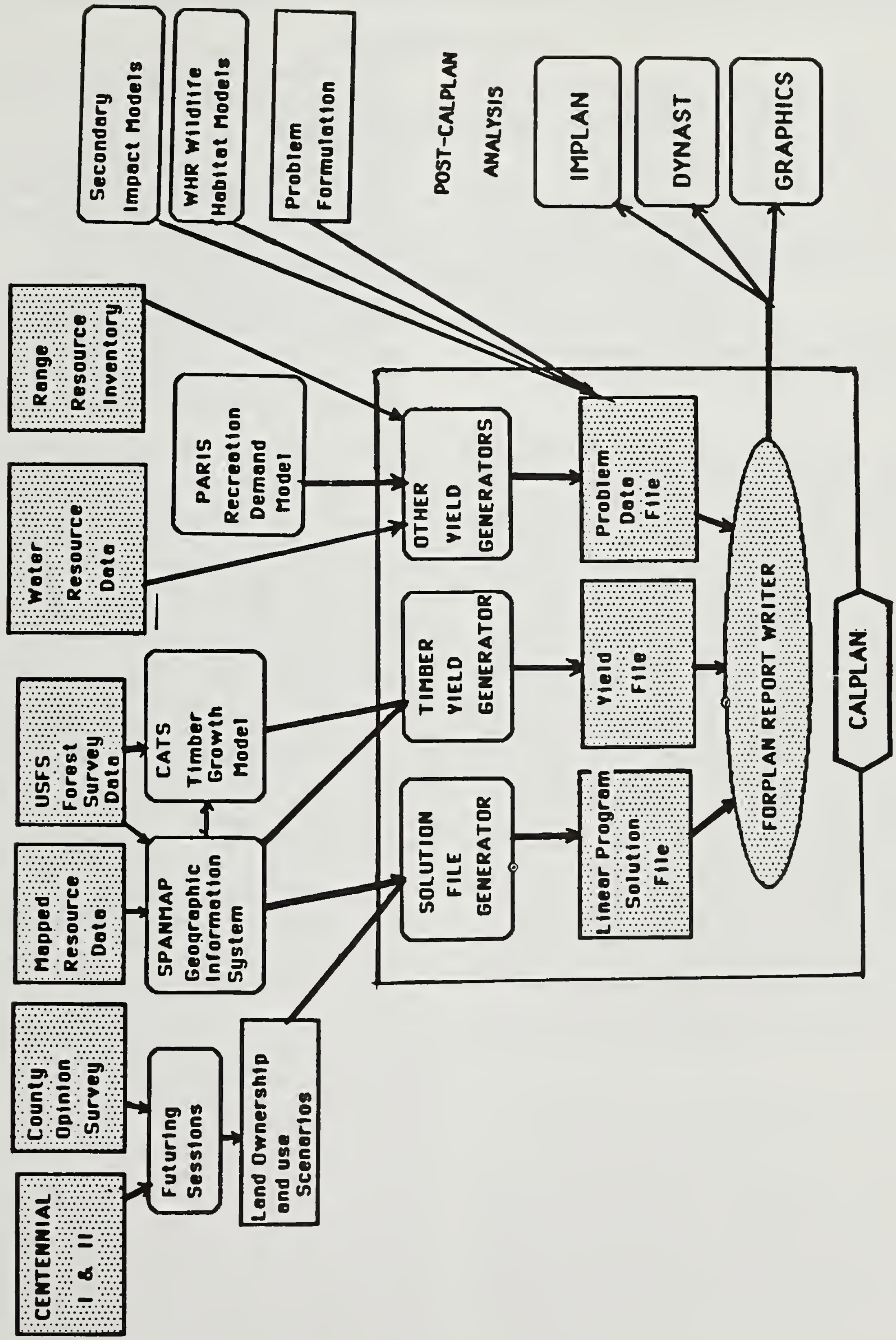

Figure 1.--CALPLAN: The California Forest and Rangeland Assessment Model; principal data and computational elements.

big enough sample to reliably estimate regional, state or national implications.

Besides the data cost, the parent institution and one or more faculty (or other long-term personnel) must invest in setting up the training, student, consulting, and computer system infrastructure needed to effectively run a FORPLAN based research program. I think we could fruitfully explore some sort of a consortium or multi-university network in some sort of a partnership with the Forest Service to share knowledge, data sets, and training to make better use of our limited resources.

Regardless of cost or difficulty - it's exciting that FORPLAN finally gives us a tool to do empirical research on complex forest level management problems.

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Boise Cascade Corporation: The FORPLAN Experience

Walt Mott and Seth Peters[1]

Abstract.--This paper discusses the linear programming capabilities, validity, and history of FORPLAN at Boise Cascade, along with the philosophy, modeling importance and source code modifications necessary for the successful implementation and use of FORPLAN in managing the Company's timberland asset.

Boise Cascade Corporation is an integrated forest products company engaged in the manufacture, sale and distribution of paper, office products, packaging and building products, both domestically and abroad. To support these operations in the U.S. and Canada, Boise Cascade manages over 6,000,000 acres of timberlands. These timberlands are managed by 13 operating regions spread across the continental United States and the Province of Ontario Canada. Recognizing that these timberlands represent a tremendous investment -- millions of dollars for the company -- it is not surprising that the company will continue to search for the best methods to manage these lands. Whether these methods result from new technologies, new or revised silvicultural practices or the use of quantitative models for better understanding our regional forests, we are dedicated to bringing our timberlands up to their full biological and economic potential. The objectives for our forest management program reflect this viewpoint. These objectives are:

1. Maintain a continuous and dependable supply of raw material for sale, trade or conversion.
2. Maximize the pretax return on total capital (PROTC) over the long term from our owned and controlled timberlands.

Both objectives emphasize that timberlands are not to be managed for only short-term gain. We believe the "long-term going concern" philosophy is the most efficient managerial approach to provide society with the quality products that it demands at the lowest possible cost. Trees take time to mature into resources that can be used to make paper and solid wood products, requiring long-term investment, managerial outlooks, budgets and plans. With such long-term biological outlooks and financial return periods and with timber availability and prices facing an unknown future, it is crucial that we improve our ability to effectively manage our forests to remain competitive in a very tough operating and investment environment.

The second objective recognizes and emphasizes that timberlands are an asset and, as such, must provide an adequate return to the corporation. The use of monetary measures for evaluating our timberlands is essential. Our performance is based on how well we operate and the return provided to shareholders and society, within the confines of the environmental, social and political responsibilities of our operations.

To achieve these objectives requires us to find the best set of forest management plans for our operating regions over time. This involves analyzing a variety of silvicultural options and harvest strategies for each timber stand and evaluating how these relate to the productivity of the regional forest. In addition, a variety of future economic and political scenarios are analyzed in order to remain sensitive and flexible to the changing external environment which directly and indirectly affects the way we do business. To help us in these efforts, a continuous forest inventory system and a management and geographical information system is maintained in each of our regions. Also, a variety of quantitative models are used for evaluating forest management planning options and issues.

One type of modeling technique we use extensively is linear programming. In particular, many of the design features available within the FORPLAN modeling regime have greatly enhanced the capabilities and utility of using a linear programming approach for analyzing and evaluating timberland management issues at Boise Cascade.

Advantages of Linear Programming and FORPLAN

For the past 10 years, Boise Cascade has used several linear programming models as an aid in developing forest management plans. Timber-RAM, MUSYC and FORPLAN are examples. We have found that the linear programming approach provides us with some unique advantages, which, in total, are not readily available from other quantitative models. Some of the most important advantages are:

1. The recognition that a tremendous amount of software development and support has centered on the use of linear programming for timber harvest scheduling and forest planning. Linear programming is a well-developed and accepted

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mathematical technique with years of testing and research to backup procedures, algorithmic methods and reporting capabilities for detailing what the solution means. This results in a more production-oriented environment as opposed to a research- or test-oriented environment. It is simpler and more cost effective to modify existing programs to fit specific needs rather than embark on a totally new software development project. This is especially true when one considers the amount of human and physical resources required to design and develop a harvest scheduling program from scratch.

2. Linear programming models provide our regions the basis to quantify the short-term and long-term operating characteristics for the lands they manage and how these characteristics are influenced by the external environment. As such, regional and corporate planners become more sensitive about how changes in the environmental, political and economical arenas affect the operating characteristics over time. Because FORPLAN allows the user to detail important operational parameters, this model has become an important planning tool for several of our operating regions. Previous timber harvest scheduling models are rapidly becoming obsolete as more regions adopt FORPLAN modeling methods.

3. The structure of linear programming models provides the means to evaluate thousands of treatment alternatives for the regional forest. Thus, we are in a much better position for making "sound" forest management planning decisions and to remain flexible for evaluating changes in external forces which impact our business. FORPLAN is especially sensitive in this area. This is one of the major reasons FORPLAN was implemented at Boise Cascade.

4. Another important advantage of linear programs, especially FORPLAN, is the capability to define complex networks. The linear programming approach combined with FORPLAN modeling design provides the means to link discrete parcels of timberlands and associated treatment alternatives to regional forest objectives and operational requirements. Per-acre analysis from growth simulators, such as MFPS or PROGNOSIS, provide for an in-depth evaluation on the best ways to manage individual timber stands. The linear programming model combines all the per-acre analyses into a single composite representation of the regional forest and then subjects the forest to real-world operating constraints to find the best set of treatment alternatives. Given the complexity of determining an allowable cut on large ownerships, this linkage becomes an important requirement to develop a feasible forest management plan.

5. Finally, linear programming and FORPLAN also provide a quick method for evaluating the sensitivity of alternative treatments under a variety of economic, environmental and political scenarios. Previous harvest models had limitations that greatly reduced the sensitivity of alternatives. Though the optimal solution provides excellent direction for formulating a forest management plan, it is not a static finding. The solution is usually only optimal over a narrow range of operating characteristics and assumptions. Sensitivity analysis provides for evaluating what these ranges are, and visualizing what the new optimal solution looks like when the operating characteristics or assumptions are changed. This type of approach is a necessity in the development of a flexible management plan.

Why Use FORPLAN?

The original purpose for linear programs such as Timber-RAM and MUSYC was to determine long-term strategic allowable cut figures, as well as analyzing timberland acquisitions and divestitures. We, at Boise Cascade, wanted something that is sensitive to long-term growth and harvest patterns, and also would allow us to evaluate the resulting impact on the periodic allowable cut. Some of the older allowable cut calculation techniques, such as Von Mantel's formula, Handeshagen's formula or harvest figures based on short-term inventory growth data are very insensitive to long-term, changing forest structure characteristics. It is often difficult, at best, for these techniques to take into account the allowable cut effect.

We also desired a technique that could be used to look at various levels of management and hence, carry out sensitivity analysis on a rapid, comprehensive, cost-effective basis. This allows us to have a conceptual understanding of the possible ramifications of a large-scale change in the management of our timberlands resulting from internal or external environmental, political or economic influences and to be better prepared to deal effectively with these changes in a time-efficient manner.

FORPLAN is well suited for addressing these issues. Once the basic model is built, the various components and linkages that comprise the FORPLAN modeling regime provide users the ability to quickly and easily create a variety of scenarios for describing future markets and operating conditions. Thus we can evaluate the trade-offs that occur both biologically and economically that is a result of a change in how we manage our timberlands.

FORPLAN has been modified to include financial information, such as cash flow, depletion, capitalized investment, net income, capital gains tax, ordinary tax, PROTC and the internal rate of return (IRR). These financial variables, along with the biological results of a model run, are often effectively used to evaluate short-term and long-term impacts of a given management approach as acquisition or divestiture opportunity. Crucial variables

such as the allowable cut, net income, cash flow and return on investment can be ascertained helping us to make better decisions about the validity of a given strategy or transaction.

Another area where we use FORPLAN effectively is in silviculture sensitivity analysis, both from a biological and a financial viewpoint. Alternative silvicultural scenarios are created for each stand or timber type and FORPLAN model runs are made addressing certain biological and financial goals. As an example, if a given model structure using today's financial assumptions is run addressing two differing goals -- one of maximizing the net present value (NPV) and one maximizing volume -- the harvest levels, NPV and silvicultural investment levels are often dramatically different. The results of these runs tell us which silvicultural options over the long term meet given financial hurdle rates. Those that do not are often deferred or eliminated as a valid management alternative (unless required by federal, state or local legislation). Those that do meet minimum return rates are emphasized in the silvicultural program.

Operating Goals

We have several important operating requirements for all our linear programs, including FORPLAN. They must be cost effective, as user-friendly as possible and must contain financial information. We put forth much programmer effort to make these programs user-friendly by simplifying input requirements, creating easy-to-understand, comprehensive reports and programming the internal code to optimize operating characteristics of the model. With the size and complexity of programs that address large, complex problems such as allowable cut determination, this is often very difficult to achieve.

To improve the effectiveness and increase the utilization of our models, we attempt to assemble a team with solid modeling background and combine it with up-to-date, cost-effective technology which results in more acceptable real-world answers. We have succeeded in pulling together a group of people who have a background in forestry, economics and operations research. These people work together with operational foresters in designing a large-scale analysis. This combination of skills is necessary to successfully design, solve and implement a linear programming model. Regional foresters are experts on the timberlands they manage, but they often do not have the time nor do they have the experience and skills to build a FORPLAN model from scratch and interpret the resulting solution output.

Interpretation of LP output must be done carefully because of the inherent limitations of any model. Confusion often arises about the validity of the answer or even why a certain optimal solution was reached. Generalized assumptions with no understanding of solution findings can lead to erroneous implementation or planning and budgeting. Having a team of experts helps alleviate these problems by working closely with our operating regions throughout all phases of an allowable cut analysis. In actuality, it is the field personnel who design the model; the team of experts help the regions input data into the model, and interpret results. Therefore, it is through a cooperative effort from both analytical and operational experts that a successful modeling application is achieved.

Boise Cascade's Version of FORPLAN

To help achieve these goals, Boise Cascade has spent more than 5 years of labor in understanding, modifying and implementing FORPLAN (Version 2, Release 3). The effort devoted toward adapting FORPLAN to fit our forest management planning needs has been money well spent. We made these changes after reviewing the model's capabilities and realizing that many of the features available within the FORPLAN framework make this modeling approach vastly superior to other timber harvest models previously used. From our viewpoint, FORPLAN provides the following advantages:

1. The multispecies/multiproduct modeling feature provides the means to link the product demand requirements of our manufacturing operations to our forest inventories. Though a single-weighted average measure of timber volume that reflects a given species/product mix, such as that used by the MUSYC model, may suffice for addressing general forest planning issues, it becomes rather burdensome when trying to accurately and realistically match it to the timber resource requirements of our manufacturing facilities. Each mill has a certain range of species, piece-size and timber volume requirements which it must have to stay profitable. The closer these are modeled within a forest planning framework, the better off we are in evaluating potential inventory/product levels and how they impact operational plans and profits.

2. The ability to define unique activities, outputs, aggregates and associated yields, constraints and economics increases the realism of the model and thus, its general acceptance. Typically, a regional FORPLAN model will use, in total, 20 activities and outputs for describing the silvicultural treatments and harvest options under study. Avoiding superfluous minutiae is critical in a model's structure. Important variables which are known to be sensitive to the internal and external operational environment must be defined and emphasized. Using a relatively small set of activities and outputs, we can not only accurately and realistically portray a silvicultural practice, but also define and evaluate its economic implications under the auspices of an investment analysis approach without confounding the analysis or implementation with unnecessary complexity.

3. The ease and flexibility for entering economics into the model is also a very important advantage. Previous timber harvest models e.g.,

MUSYC, required the user to develop a rigid economic look-up file which was used with other model input found in the processing file. For small linear programming models, this file structure was workable; however, in larger models in which a variety of economic scenarios were being explored, the MUSYC file structure was cumbersome. Whenever a revenue or cost was changed, every economic table for which the change applied would require modification. For a small number of changes, the appropriate economic tables are easily modified; however, with substantial changes in economics, the user had to create a new economic file. This resulted in a less cost-effective model that also took a longer time to restructure. Sometimes, where very quick answers were needed, it was impossible to use the model at all. Therefore, the tool became ineffective for decisionmaking.

Within the FORPLAN modeling regime, all economics are entered directly into the processing file based on stand or volume characteristics instead of being directly linked to a given forest entity/age value. This allows economics to be easily modified, and by using a combination of identifiers, qualifiers and treatment types, it is simple to attach a set of economics to the entire forest or to a unique analysis area prescription combination.

4. FORPLAN provides several other economic features which were nonexistent in other timber harvest models. The ability to define a unique species/product set of real appreciation rates for each activity or output lends more realism for modeling "real-world" phenomena. For example, in the southern region of the United States, we know that the value and appreciation rates for pine sawtimber is markedly different from hardwood sawtimber. Using one value or set of appreciation rates may work fine as a general starting point but is in error when applied to evaluating future markets and operational plans. This is especially true when trying to evaluate shifts in the species- product mix and their economic impact on regional timber supplies.

5. The power of qualifiers for defining a set of economics over a range of activity or output yields is also very important. For example, qualifiers are used in developing logging costs to account for the large cost variations that occur because of product piece size or diameter class.

6. The use of identifiers and in particular, the ability to define the identifier-matching strategies (THEMING) for linking various components of a model together is a powerful feature of FORPLAN. Throughout the FORPLAN modeling regime, the efficient ise of identifiers can decrease data input requirements, which, in turn, help to minimize the size of the processing file and yield file, and related disk storage and processing costs. We have found that the proper use of identifiers can save us hundreds of dollars within a model application. Based on this finding, a set of worksheets and procedures were developed for use by our regions when designing a regional model to take advantage of the power and flexibility of identifiers and their linking capabilities.

7. The ability to create an individual column within the linear programming matrix using "direct entry" is also important. In each of our regions, we have found that there are some prescriptions which cannot be accurately represented using the yield file and yield composite components. In these situations, the direct entry approach allows us to realistically and accurately portray and define both the timing and yields of the activities and outputs which comprise a particular prescription.

In review, we believe that the features provided within FORPLAN allow us to more realistically and accurately describe our regional forests and also represent the real-world operational, environmental and economic considerations within which we operate. Though FORPLAN provides for considerable model definition, we only use what is necessary to address a set of preconceived questions and issues which are important. Used this way, FORPLAN modeling results can be more closely matched to actual timber stands and silvicultural operations with the microeconomic considerations of the region. In addition, using a small set of questions and issues should allow forest planners to focus their attention on the major internal and external issues without getting bogged down in minutiae. In total, FORPLAN has proven itself to be a powerful decision-making tool and has gained in acceptance and use as the preferred modeling method for evaluating forest planning issues at Boise Cascade.

As previously mentioned, a considerable amount of time and money was spent in implementing FORPLAN at Boise Cascade. To successfully implement the model, we were required to modify source code, and design strategies and procedures to better represent our operating environment. The revisions have centered on three major areas. First, several new features to the source code were added to accurately represent the economic climate. These features enhance the financial characteristics of the input requirements of the model, so that we can evaluate our regional timberlands using an investment analysis approach. Two new reports were added to the report writer which summarize important financial and investment information.

Second, the source code was modified to correct several of the known errors as reported in the USDA FORPLAN Users Guide. In addition, we reformatted all output from the matrix generator and report writer modules to meet our reporting needs. Because many of these reports are reviewed by top and middle management, it is crucial that each report is clear, concise, and easy to read. This reduces the need for an intermediate step of pulling numbers

together on a piece of paper and having it typed. Instead, the computer can create reports, saving time and costs.

Finally, we have modified some of the logic on how the model works. These modifications have focused on two major areas. First, a set of JCL procedures were designed to adapt FORPLAN within an IBM 370 operating environment. These procedures were structured to maximize the operating efficiency of the model without seriously degrading our total data processing resources during model runs. Because the JCL procedures were rather complex, it was important to make these procedures user-friendly. This was accomplished by storing all information related to the opening and closing of files within a set of procedures transparent to the user. The JCL seen by the user, asked for simple input requirements (e.g., "What is the name of your processing file?").

The second logic modification occurred in the report writer module of FORPLAN. Because of our LP solver and other system requirements, the source code was redesigned to increase the speed of report writer runs by eliminating redundant calculations. As an example, before the code was modified, a typical report writer run took over 6 1/2 hours. With the modifications, this same run now takes less than eight minutes. This increase in efficiency has reduced the costs of a report writer run by 90%. As such, operating regions can now run the report writer as often as needed with minimal impact on other users of the corporate data processing resources.

To help the regions implement our version of FORPLAN, two manuals were developed: (1) a "Users Guide" and (2) a "FORPLAN MODEL EXAMPLE." The "Users Guide" has three purposes:

- To provide a modeling framework which describes the essential components of FORPLAN and shows how these components are related. This framework provides the basis on which a regional model is built.

- To describe how to build a FORPLAN model with emphasis on rules and limits for data input. Examples are provided to enhance user understanding of these model building requirements.

- To recommend several model building techniques which help minimize the costs of model development without sacrificing the comprehensiveness and accuracy of a forest planning analysis.

The "FORPLAN EXAMPLE MODEL" manual is used to describe and show correct data input for a typical regional forest modeling effort.

Where Do We Go from Here?

With the effort spent on FORPLAN and anticipating what new features or requirements our regions would like to see in the model, additional enhancements are being considered. First, we are contemplating restructuring the logic behind use of yield tables to increase the efficiency, in terms of both time and money, of matrix generation runs. In particular, we want to reduce Yield File I/O to provide better utilization of a yield table once it is read into memory.

Second, we have recently acquired the latest IBM version of FORPLAN (Release 10) and would like to merge this release with all our coding changes.

Finally, we are exploring the feasibility of expanding the capabilities of the objective function in at least two ways. First, we want to add additional objectives, such as to maximize cash flow and to maximize PROTC. Second, we are exploring the feasibility for providing users the capability to regenerate the objective function coefficients, in total or in part, without having to make a complete matrix generation run. The goal of all these is to reduce the cost of a FORPLAN model as much as possible, making it more attractive as an analytical tool.

Summary

In summary, both corporate and regional forest planners agree that FORPLAN capabilities allow more real-world influences to be considered than previous timber harvest scheduling models. This is important from an analytical viewpoint, but it can be even more critical from an implementation perspective. If the quantitative analysis cannot be tied back to actual practice, then the results are fruitless. We believe that FORPLAN provides us the capabilities to realistically and accurately describe our regional forests and the internal and external forces which impact our forest plans. We expect that future FORPLAN models will continue to play an important role in the management of the second largest asset Boise Cascade owns -- our timberlands.

British Columbia's Experience with FORPLAN

Lois H. Dellert[1]

Abstract.--Because of British Columbia's land management and resource planning requirements, its approach to modeling, and its priority on resource planning, it has decided not to use FORPLAN. Also, FORPLAN models have proven to be difficult for managers to understand. As FORPLAN evolves and British Columbia circumstances change, it will continue to evaluate the system.

The title of my paper is "British Columbia's Experience With FORPLAN." However, British Columbia is not using FORPLAN, and, based on an evaluation of its suitability, does not intend to use FORPLAN. There are three reasons for this decision:

1. British Columbia's land management and resource planning requirements are different from those in the U.S.A.;
2. British Columbia has chosen a "component approach" to modeling rather than using a single large model; and
3. Given the priority placed on resource planning in British Columbia, the resources are not available to implement FORPLAN.

My paper, therefore, would be better titled "British Columbia's Evaluation of FORPLAN" as it will discuss in more detail the rationale behind each of these three reasons.

British Columbia has successfully used two American planning models, Timber Resource Allocation Method (Timber RAM, Navon 1971) and Multiple Use Sustained Yield Calculation (MUSYC, Johnson and Jones 1979), to provide analytical support for strategic timber supply planning. As there seemed to be parallels in the evolution of forest planning north and south of the border, we were curious about the new American planning model, FORest PLANning model (Johnson 1979), Should British Columbia move on from using MUSYC to using the latest generation planning model, FORPLAN?

Early attempts to acquire and test FORPLAN were severely hampered by two factors. The British Columbia government's computing environment is IBM,[2] and an IBM version of FORPLAN was not readily available. The second factor was lack of information. It was difficult to find out anything about the model. What was heard about it through word of mouth was not encouraging. The impression one got of FORPLAN was of a data-hungry monster whose appetite took person-years to fill, and which regurgitated an incomprehensible solution leaving no option but to accept it as "the optimal." With the amount of bad press FORPLAN was getting, we began to question its usefulness in British Columbia.

The British Columbia Forest Service finally acquired an IBM copy of FORPLAN, version 2, in 1984 and managed to get the model running with the sample data set supplied. However, this did little to help understand the model, because the terminology and planning approach were significantly different from those of Timber RAM and MUSYC with which we were familiar. At that point, the only documentation available to us was a user's guide which was too specific to be of much use in evaluating the model. Because of the frustration this caused, combined with other priorities, FORPLAN was put aside. Interest in FORPLAN was again piqued last December when I attended a short course in Corvallis. Norm Johnson provided excellent instruction and, for the first time, I grasped the concept of FORPLAN. The course, along with the overview documentation, finally provided enough insight to rationally evaluate the model's suitability in British Columbia.

The balance of my paper focuses on this evaluation and the reasons British Columbia decided not to implement FORPLAN.

BRITISH COLUMBIA'S EVALUATION OF FORPLAN

Is FORPLAN a Suitable Model to Meet British Columbia's Land Management and Resource Planning Requirements?

Although FORPLAN evolved from a series of timber scheduling models, it has developed into a land allocation model to meet the specific requirements of American legislation and policies (Iverson and Alston 1986).

Although there are many similarities north and south of the border, there are also several key differences which have an impact on the use of FORPLAN. To evaluate FORPLAN's suitability in British Columbia, our land

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[2]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

management and resource planning requirements must be considered and compared with those in the U.S.A.

British Columbia is Canada's most western province bounded by the 49th parallel to the south, the 60th parallel to the north, the Canadian Rockies to the east and the Pacific Ocean to the west. The total province area is about 90 million hectares (222 million acres), of which more than 90% is publicly owned. Of the total area, 50% is classified as productive forest land and only 25% or 22 million hectares (54 million acres), as defined through our planning process, is operable and suitable for timber harvesting. The total annual timber harvest from this 22 million hectares is about 75 million m^3 (26 million cunits). Harvesting is still primarily located in old growth stands and the age class distribution is predominantly mature with only 8% of the productive forest land less than 80 years old. (British Columbia Forest and Range Resource Analysis, 1984).

The total population of British Columbia is 2.5 million, with fewer than 1 million outside greater Vancouver. There are large tracts of forested land in sparsely populated areas which can be managed primarily for timber. British Columbia's forests are extensive and remote compared with the U.S. South, for example, and are most similar to those of the Pacific Northwest and Alaska.

Responsibility for the management of the forest resource lies solely with the provincial government. Within the province, the mandate is divided between several ministries with the Forest Service of the Ministry of Forests and Lands having the responsibility for timber, range, and recreation from public lands. Other Ministries are responsible for wildlife, fisheries, parks, and mineral development. Although the Forest Service has the dominant position, there is no central land management planning agency or interdisciplinary planning system.

The basic objectives of the Forest Service are established in Section 4 of the **Ministry of Forests Act** and include the forest planning mandate "to:

(a) encourage maximum productivity of the forest and range resources in the Province;

(b) manage, protect and conserve the forest and range resources of the Crown, having regard to the immediate and long term economic and social benefits they may confer on the Province;

(c) plan the use of the forest and range resources of the Crown, so that the production of timber and forage, the harvesting of timber, the grazing of livestock and the realization of fisheries, wildlife, water, outdoor recreation and other natural resource values are coordinated and integrated, in consultation and cooperation with other ministries and agencies of the Crown and with the private sector;

(d) encourage a vigorous, efficient and world competitive timber processing industry in the Province; and

(e) assert the financial interest of the Crown in its forest range resources in a systematic and equitable manner."

Land management and resource planning are less tightly regulated by legislation and procedures in British Columbia than they are in the USA, and British Columbia's resource managers have much flexibility and subjectivity.

Land allocation is carried out in a broad sense by designating land that is best managed for multiple use forest and range as Provincial Forests. Approximately 94% of the public land is designated as Provincial Forest. Land can be withdrawn from a Provincial Forest only if the proposed use provides greater benefits. The benefits of different uses are assessed through localized studies for the areas in question, and the final decision is made by the politicians. No extensive land value/land allocation plans are carried out. Lands available and suitable for timber harvesting are further identified through our planning process. Areas are deleted from the land base for environmental and merchantability reasons. Timber plans are then carried out on the net land base identified.

The public forest land is divided into two different types of management units with timber harvesting rights granted through either an area-based or a volume-based tenure system. Tree Farm Licenses (TFL) are area-based tenures made up of private and public lands. TFLs are managed by private industry and comprise 27% of the total harvest.

Timber Supply Areas (TSA) are managed under a volume-based tenure system and comprise 73% of the total harvest. TSAs are large, varying in size from 500,000 ha (1,235,000 acres) to 7,500,000 ha (18,500,000 acres) and supply timber through volume licenses to as few as 2 to 3 private companies within a single TSA. These companies hold renewable licenses which authorize them to annually harvest a portion of the TSA AAC for as long as their license remains in good standing.

A TSA Plan is developed by the Forest Service for each TSA every five years and includes timber, range, and recreation production targets, management direction and the location of 20-year harvesting areas for each licensee in the TSA. The timber supply analyses carried out to support the TSA Plan are done centrally, unlike the decentralized approach in the U.S.A. Through centralization, flexibility and standardization can both be achieved.

Timber dominates in British Columbia's planning system and other resource values are recognized as constraints on timber harvesting. Timber harvesting plans are referred to other resource agencies for review and conflicts are normally settled through consultation and negotiation at a local level.

Considering these differences between British Columbia's and the U.S.A's requirements for forest planning, is FORPLAN a suitable model to carry out resource planning in British Columbia? As public concern and demand from other resource uses increases and our land management requirements change, British Columbia may evolve to use a FORPLAN land allocation approach; however, until that time, implementation of FORPLAN as a model to support land allocation and resource planning decisions would not be appropriate.

Is the FORPLAN Approach of a Large Single Model Desirable in British Columbia?

Although FORPLAN would not be used in British Columbia as a land allocation model, could it be used for timber planning? Because a major strength of FORPLAN version 2 is its flexibility to model many different problems, a British Columbia formulation probably could be developed using FORPLAN's framework. But before formulating a FORPLAN model, we would first have to determine how we could use it, where it would fit into our planning system and whether it was consistent with our modeling approach.

A model, by definition, is an abstraction of reality. Its usefulness as a decision making tool comes from its ability to simplify a complex process so that a manager may be better able to understand that process. In building a model, the balance between complexity and simplicity must be considered. If a model is too complex it may not be understandable; if it is too simple, it may not be relevant. The balance can be difficult to achieve as managers tend to want the model to make decisions and push for it to be as real as possible. This usually means a large, complex model with much detail. The modeling exercise can become more important than the decision. In British Columbia there is continual pressure from the managers to include more and more detail and many interactions in one model. This provides a challenge for the model builders to develop a model that the managers will accept, which is relevant but still understandable. Can a model be developed which incorporates all the detail and complexity requested and still be understandable? FORPLAN is an example of a model which was built to meet managers' requirements.

The FORPLAN approach of one large model which brings together many forest resources and attempts to model their interactions at once has tipped the balance between complexity and simplicity. In its attempt to model every interaction--to be very realistic-- comprehension has been forfeited. Model results must be understandable to the manager, who is the decision maker. The FORPLAN approach to model a very complex problem is admirable; but are FORPLAN results understandable? Are they interpretable? Are they used as support for decision making, or do they make the decision?

Most modelers understand that a model only supports decision making; but is this understood by the managers? If so, how can they use FORPLAN results as an aid to decision making when the model is very complex and the solutions difficult to interpret? To truly use a model as a support for decision making, it must be well understood.

If the model is large and complex, as FORPLAN can be, the model can easily be mystified and the solution either taken as given or discounted. In one case there is danger that the linear programming solution is taken as the "optimal" solution which must be adhered to as it is perceived to be the best. How many times have you heard, "but the model said..."? Conversely, in the other case if the results of an analysis are not in line with perception or local intuition, and if the modeling process is viewed as a large black box, the model solution will not be accepted willingly. In both of these cases the model provides little help to managers. This was expressed as an "information and understanding gap" and identified as a "barrier to planning" in the Ottawa National Forest (Voytas 1986).

This problem of comprehension could be partially overcome through education, but the education task becomes formidable because FORPLAN is a complex model, and the public as well as the forest managers must be involved. Even if the decision makers and the public understood how FORPLAN worked, could they or anybody else intelligently interpret a complex FORPLAN solution?

Simple problems can be formulated, because FORPLAN is not a really single model, but a framework within which many models can be formulated. Experience shows that an analysis usually reaches the limits of a model, and that if the capacity and capability of the model are expanded the analysis grows to that new limit. It is not the user of the tool or the manager who will usually volunteer to keep the analysis simple but the model which, through its limits, forces simplicity. The model-developers have a responsibility to build understandable models.

The need for comprehension becomes very important because resource planning is not limited to biophysical and economic criteria, which can be modeled, but includes much socio-economic concerns which require a human element. Analytical techniques such as FORPLAN cannot provide the means to resolve resource management issues, but simply provide sharper focus for decision makers. A planning process is required that will provide a framework which permits the use of models as aids and includes a large degree of human input and decision making throughout the process. As a District Ranger from White River National Forest stated, "there is always an ultimate limit to the value of a FORPLAN solution in multiple use management no matter how sophisticated we chose to make our model" (Troyer 1986). Analyses must be understood by the decision-makers in order that the results can be used intelligently and non-quantifiable values can be incorporated into decision making.

British Columbia has decided to pursue a "component approach" to modeling. Within a planning framework, several models, processes or systems, provide support for decision making. The components span several levels of planning and provide the ability to assess many resource use and timber issues. The focus is on the planning process and not on the planning model.

An example of this component approach is illustrated in TSA Planning. Timber supply analyses for TSAs have two components: long-term harvest projections leading to the determination of an Allowable Annual Cut (AAC) and selection of an overall management direction; and the geographic location and scheduling of 20-year harvesting areas for each licensee within the TSA. A component is envisioned which will be geographically specific and provide for the allocation of harvest for a 20-year period to various licensees within the TSA. The short-term strategies developed then would be evaluated for their sustainability by linking to a separate long-term harvest projection model or models. The two components provide for a 20-year time frame, geographic resolution, and long-term assessment resulting in a plan which is relevant and implementable without foregoing detail or a long-term view.

Working against the component approach are the difficulties in achieving linkages between the components.

Linkages between the short-term harvest allocation and long-term harvest projections and between land allocation and timber planning, for example, have been difficult to achieve and pose challenges to modelers. Innovation is required in obtaining these linkages; the modeling effort should be directed here.

When we first looked at FORPLAN we were excited about the potential to link the short and long-term aspects of timber supply planning in one model formulation rather than using separate models. The two features of FORPLAN that were of most interest were the ability to specify variable period lengths and the use of allocation zones to provide geographic resolution. These features could provide the capability to include a detailed, geographic specific 20 year "front end" linked directly to a less detailed long-term "tail end." This would provide the resolution required for 20 year planning and the linkage required to ensure long-term objectives of sustained yield. With closer review, we realized that FORPLAN would not only need variable period lengths, but also would require the specification of varying geographic detail. The overhead of maintaining the geographic resolution required (500 to 2,000 planning cells) throughout the whole planning horizon would be too high. We retreated from the concept of one model to do both short and long-term planning and are now looking for two separate but linked approaches.

FORPLAN could be used to carry out long-term harvest projections, but is it the best choice? As the long-term aspects of the plan are de-emphasized, a simpler model, such as MUSYC, may be more appropriate and is already in use.

FORPLAN also could be used to carry out the 20-year allocation; but does it allow for sufficient geographic resolution? Can it be linked with a geographic information system and can it be linked to a long-term projection model? These questions for the most part have been left unanswered, because FORPLAN has not been used in this manner and would require much more detailed investigation and research.

Perhaps FORPLAN could change its focus and provide a basic framework with which other components, such as a fire and pest model, geographic information system, or a timber allocation model could be linked. British Columbia would be very interested in any future efforts to simplify FORPLAN and to link it with other models, systems and levels of planning.

Could FORPLAN Be Implemented in British Columbia?

The ability to implement FORPLAN was an important consideration in our evaluation as it directly relates to the model's success. Our evaluation considered many factors, technical and human.

The Formulation of a British Columbia Model.

Before using FORPLAN operationally, a major research project would have to formulate a British Columbia problem, link with our data preparation systems, and train the analysts and managers. Until recently, the Forest Service's planning systems development team consisted of one forester. This team soon will be expanded to include one other forester and a systems analyst; however, without additional resources, the implementation of FORPLAN would use 100% of our development resources for at least 1 year. Considering other priorities, the Forest Service could not afford to expend all its resources on FORPLAN.

Staff and Expertise to Use FORPLAN

The planning resources in the Forest Service consist of 12 staff in Victoria, 3 in each of 6 Regions and 1 in some of 46 Districts for a possible total of 76. The total operating budget is less than $1 million. That works out to about 1 planner and $10,000 for every 1 million m^3 (350,000 cunits) harvested annually.

Hands-on experience using forest planning models is limited to six staff in Victoria. Knowledge of FORPLAN in British Columbia is limited to myself, one consultant firm and a graduate student at the University of British Columbia. Our understanding of FORPLAN is general and includes very little hands-on use. Because of FORPLAN's complexity, a major commitment would have to be made to increase our knowledge pool and to educate and train both the analysts and the managers to ensure successful implementation. Limited resources, other priorities and lack of expertise severely hamper our ability to do this.

Computing Environment.

The British Columbia government's computing facility is IBM. Although several IBM versions of FORPLAN have been released, IBM compatibility does not appear to be a high priority of the USDA Forest Service. We would require full support for IBM compatibility before implementing FORPLAN to ensure full support of the model.

Documentation

Documentation of FORPLAN has been slow. However, documentation now exists and FORPLAN appears to be well supported. Hopefully the documentation can now keep up with further development as it is essential for external users who don't have the benefit of internal, informed support and networks.

Data Requirements

The data requirements to use FORPLAN can be enormous. Although we have an excellent forest inventory, data for resource values other than timber are difficult to generate as much of the information is not quantified or compatible. It would take a large allocation of resources

and a long time to generate much of the information required.

Considering all of these factors, along with the complexity of FORPLAN, the implementation of FORPLAN in British Columbia would be a formidable task.

SUMMARY

The Forest Service has chosen not to implement FORPLAN; but we are continuing to assess FORPLAN for its suitability in light of projected changes in British Columbia's modeling requirements and in the evolution of FORPLAN.

British Columbia's requirements for resource planning models are changing. Resource planning is evolving in British Columbia as public awareness of and demand for other resource values and better management increases. However, given the differences outlined in this paper, resource planning in British Columbia may or may not evolve in the same manner as the in the USA. As our requirements change, we will continue to evaluate American resource planning models, including FORPLAN, for their suitability.

We are curious about the future of FORPLAN. If it can be simplified, easily linked with other planning models including a geographic information system to become part of an overall planning system, and can be supported on an IBM system, it may provide a useful planning tool for British Columbia.

Although British Columbia has not implemented FORPLAN, we have learned much from it which will help us to develop and use resource planning models. I hope that my comments have provided you with some insight and will help you in future modeling endeavors. We will be following FORPLAN's evolution with interest.

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The North Carolina State University Experience with FORPLAN: Software Transfer and Example Of Use

Joseph P. Roise and John Welker[1]

Abstract.--NCSU required the use of FORPLAN software for several management research projects. FORPLAN software was obtained through the University of California, Berkeley. Several steps are discussed on how FORPLAN was transferred for use at NCSU. The first applications of FORPLAN at NCSU, a national planning model for Jamaica, is also discussed.

The print out of the FORPLAN code requires 0.2 cubic feet of paper, weighing in at 9.7 lbs. It would take a loblolly pine seed in average soil about 16 years to make the wood for this print out. No big deal when compared with the amount of fiber in the national forests. However.....

In the summer of 1985 the Department of Forestry at North Carolina State University acquired a tape containing FORPLAN software from the University of California, Berkeley (UCB). At UCB FORPLAN is running on the IBM-Conversational Monitor System (CMS), and because one of our campus computer systems used IBM-CMS, our hopes were high that we would soon be running FORPLAN. On the first day the program was loaded into CMS, FORPLAN could be started using the EXEC (execution) language program supplied by UCB with the rest of the FORPLAN files. On the same day our problems began.

On the NCSU CMS system the standard secondary memory allocation is less than one cylinder. FORPLAN required 35 cylinders of space. This results in quite an expense just to store the model.

The EXEC program was failing on some system software differences between UCB's and NCSU's version of CMS. These needed to be reconciled.

The most serious problem was that the solution software required for this version of FORPLAN is MPSX. Not only was this software not on the CMS system, but the campus had discontinued its use on all systems in favor of another large scale LP solution package. However, there was a version of MPS kept on another IBM computer system using the Time Sharing Option (TSO) operating system. The original install tape for MPS was located but because of age (original installation around 1975) the magnetic fields on the tape had deteriorated beyond the background noise level. The tape could not be read. At this point we considered two options. Either we could: (1) generate the matrix on CMS and send the matrix file to TSO, through a filter to remove discrepancies between MPS and MPSX, solve the problem on MPS, send the results through an output filter, and back to CMS to the report generator; or (2) we could move FORPLAN to the TSO system, and do all the calculations on one system. Because of the size of the problems we were working with, we felt it would be best to do all work on one system. Notice that one possible option was not included: buying or leasing MPSX. The cost of MPSX was around $17,000 and our initial budget to get FORPLAN running was less than $10,000. In hind sight, it may have been less expensive to buy MPSX and load it onto CMS.

During the summer and fall of 1986, we installed FORPLAN on the TSO system for the North Carolina State University School of Forest Resources. This document contains two major sections the first describes the strategy and specific steps taken while installing FORPLAN and the second discusses an application in planning Jamaica's forest resources.

INSTALLATION OF FORPLAN

This section has two parts. The first outlines a general strategy for installing any program like Forplan and the second section details the specific steps taken while installing FORPLAN at NCSU.

General Strategy for Installing FORPLAN

There are at least four major steps required when installing a program like FORPLAN. The first step is determining whether available computers have the hardware needed to execute the program. After finding a computer system, the second step is moving the files with the source code onto that computer system. Once all the files with the source code are on the computer system, the third step is translating the source code into executable code. After supplying the computer system with executable code, the fourth step is supplying the executing program with data in a usable format. Each remaining paragraph, in this section, provides succinct elaboration on each of these four steps.

Before acquiring a computer program, determine whether the available computers have enough

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hardware to allow the program to execute. The hardware of a computer system consists of a central processing unit, an arithmetic/logic unit, random access memory and peripheral input/output devices. Distributors of programs usually provide a list of the hardware required to allow the program to execute. For example, a program requiring 5 megabytes of random access memory will not execute on a computer which has only 640 kilobytes of random access memory. Similarly, a program requiring 2 tape drives, will not execute on a computer that has no tape drives. A computer system's capacity to store and access information, using devices like fixed disks and tape drives, may not only preclude execution of a program, but may not be sufficient to store the program itself.

After finding a computer system capable of storing and executing the program, the source code files are then placed into the computer system. The source code files are ASCII files which hold only information which is readable by humans. In other words, these are the files that computer programmers have entered using a keyboard. Once again, these files are written in English. These files are transported using media that the computer system supports. For example, a tape may be sufficient, given that the computer system, not only has a compatible tape drive, but also is able to read the format in which information is stored on the tape. A tape may not be the most convenient medium for moving files to a computer system. For example, the capacity to transfer files over a telephone line is sometimes more convenient.

After the source code has been stored on the computer system, the next step is to translate the source code into executable code. Files containing executable code cannot be read by people, but they can be read and used by computers. Requirements for consolidating source code into executable code vary depending on the complexity and structure of the computer program. For example, a simple program may only require one compile step, one link step and one go step. Where the compiler translates source code into an object module, the linker translates an object module into a load module and the go step loads and executes the load module. However, complex programs, such as FORPLAN, may require several compile and link steps before the go step. Each file holding source code is first translated into an object module, and second, each object module is cross referenced, by the linker, and stored, as a load module, in a library of load modules (this library is usually stored as a partitioned data set). After all source files have been stored as load modules, the computer program is ready for execution.

After supplying the computer system with executable code, data must be made available in the format expected by the program. Because data can be accessed using any one or more of several devices, it is necessary to know which devices the computer program expects to use. Additionally, it is necessary to know the precise method for presenting data to the computer program. For example, it may be necessary to provide data which establishes initial conditions before presenting that data pertinent to a particular problem. Also, the physical arrangement of data may vary from one computer program to the next. For example, the computer program may require that the data consist of a certain number of lines and that each line be presented in a particular columnar format.

When an adequate computer system has been supplied with an executable program and the data expected by that computer program, the process of installation is finished. When installation is finished, the process of use and maintenance begins. Using a program can be a formidable task simply because the data required may be expensive to supply, alter and maintain. The costs associated with using a program almost always overshadow the costs incurred while installing that program.

Adapting the General Strategy To Install FORPLAN

Having established the events required to install a program like FORPLAN, the following outline reconciles that general strategy with the steps taken during installation. Each of the numbered steps, in the following outline, corresponds to an event which occurred while installing FORPLAN. As each objective in the general strategy is accomplished, it is noted with commentary.

1. Reconcile hardware requirements with available computer system.

   The tape with the source code needed to install FORPLAN were written using the UCB equivalent of the IBM CMS TAPE DUMP command. Therefore, a computer, at NCSU, capable of reading this format was required. Additionally, FORPLAN produces files that are used as input to the IBM Mathematical Programming System, then Forplan reads and processes the output of the Mathematical Programming System. So a computer capable of operating MPS with Forplan was another requirement. Finally, Forplan requires a minimum of 2 megabytes of random access memory, a tape drive and a considerable amount of space on a disk pack.

   Having established the requirements, the next step was to evaluate the capacity of the available computer system. The NCSU computing center operates a CMS system capable of reading the tape created at UCB. The Triangle Universities' Computing Center (known as TUCC) operates a computer system capable of executing both MPS and Forplan and also has a version of MPS available.

   Having found a computer system to match the requirements, the next step was to move the files with the source code onto the computer system.

2. Receive tape from University of California at Berkeley

3. Move files from tape onto disk on CMS

4. Move subroutines from MACLIB to individual files on CMS

5. Move individual files from CMS to TSO

The source code had been stored, on tape, in a file called FORPLAN MACLIB. After loading the tape on the tape drive, the command, "TAPE LOAD FORPLAN MACLIB D1," moved the file from the tape to the D-disk. A list of files in the Maclib was displayed using the command, "MACLIB MAP FORPLAN MACLIB D1." Files stored in a CMS Maclib can be moved from the Maclib to the Punch machine using the command, "PUNCH FORPLAN MACLIB D1 MEMBER (membername)", where membername is the name of one of the files in the Maclib. The Punch command takes the files out of Maclib format and converts it into ASCII format. After moving the member from the Punch machine to disk, the file can be further processed. In our case, further processing meant moving the files from CMS at the NCSU Computing Center to TSO at the Triangle Universities' Computing Center (TUCC). The files were transferred using the electronic mail system.

Having supplied the computer system with the files containing the source code, the next step was to translate the source code into executable code.

6. Produce hard copy of the source code

7. Prepare list of all subroutines and calls to subroutines

8. Prepare files for compilation and linkage

9. Compile, link and store files in a PDS at TUCC

10. Back up all files and the PDS on tape at TUCC

Because the Forplan program consists of more than 230 separate subroutines, it required as many compilation and linkage steps. Subroutines which referred to no other subroutines were the first procedures compiled and stored in a partitioned data set. Remaining procedures were compiled and cross referenced with routines already in the PDS.

Having supplied the computer system with executable code, the last objective was to supply data to the executing program.

11. Prepare list of all read, write and format statements

12. Match the instructions in the user's manual with the read, write and format statements

13. Establish files required to execute Forplan

Files containing the source code were processed to produce a list of all Read, Write and Format statements. These statements were cross referenced with the user's manual to determine which files are required by each module of Forplan.

14. Write command procedure to coordinate the execution of Forplan's modules and MPS

This step is unique to installing Forplan. The Forplan program is actually a set of separate programs, the execution of which, must be coordinated. Results are passed, using files, from one module to the next. A command procedure coordinates the execution of modules depending on the information stored in the files that are passed from one module to the next.

FOREST PLANNING MODEL FOR JAMAICA

The initial use of Version 2 FORPLAN at North Carolina State University is to examine the current pine lumber import substitution strategy of Jamaica. In the early 1960's the Forestry Department of Jamaica began establishment of *Pinus caribaea* var. *hondurensis* (PCH) plantations in the eastern and generally mountainous portion of the island. The objectives were to provide watershed protection and to substitute for lumber imports, primarily from the southeastern United States and Central America. In 1986 there are about 10,000 hectares in pine plantations on government lands (FIDCO 1986). A smaller area of pine plantations also exist on private lands. About 60,000 additional hectares in the eastern portion of the island have soils suitable for PCH (FIDCO 1986).

In 1978 a state-owned company, Forest Industries Development Corporation (FIDCO), was formed with the "objective of developing the potential for commercial forestry and forest industries in keeping with the nation's strategy of import substitution, job creation, and optimum land utilization" (FIDCO 1979). Harvesting and sawmill operations for lumber production began in 1979. In 1985 FIDCO produced 4.8 million board feet of import grade lumber, representing 19% of total consumption of this grade. Inferior grades of lumber and treated posts are also produced.

Soil and rainfall conditions permit high growth rates, between 15 and 27 cubic meters per hectare per year on a 20-year rotation. Also, the FIDCO sawmill is running on a single shift basis so that production could be expanded with an increase in log supply. However, about 75% of the suitable forest land requires skyline harvesting. In addition, both coffee and mixed agriculture compete for land use over much of the area, particularly following forest road development. The compatibility of forest plantation wood production and watershed management is also a significant issue for those lands near Kingston.

Jamaica's location, and favorable credit arrangements in recent years, account for the current role of the United States as the major supplier of coniferous lumber. However, the long-term trend of total consumption of import grade coniferous lumber has declined over the past 20 years, -0.8% per year (External Trade Bulletins, 1966-1985). Constant real income per capita, increasing import supply prices (1.2% per year), and increases in duties contribute to the decline. In April 1986 the effective duty on lumber imports was increased from 9% to 27% which should further reduce consumption and imports.

Policy Issues

The principal policy issue in this context is that of determining the appropriate land use strategy given current knowledge of production possibilities and factor and output price expectations. The three graphs in figure 1 illustrate the conceptual model for determining the lumber production equilibrium in a static context. The graphs are identical except for the domestic supply schedules, S_D, S_I and D_E represent the perfectly elastic import supply and export demand schedules respectively. In the upper graph Q_d should be produced domestically, and $Q_t - Q_d$ should be imported. In the bottom graph the equilibrium is one of autarky so that domestic production equals consumption.

The primary objective of this study is to test the hypothesis that the appropriate long-term land use strategy is one in which a combination of imports and domestic production provides the quantity demanded at the import supply price adjusted for duties and distribution costs. Additional objectives of the study are to show the import and domestic supply quantity schedules in the short-term and to test the sensitivity of the results to alternative price and policy expectations.

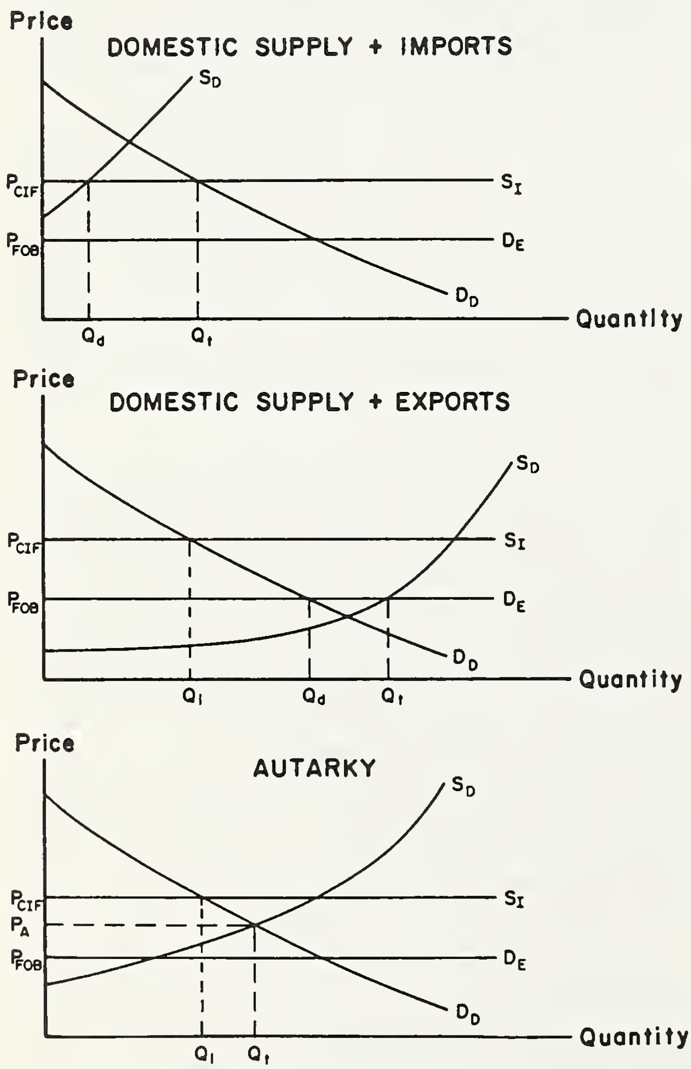

Figure 1.--Conceptual import substitution - export promotion model.

Linear Programming Model

The harvest scheduling-linear programming (LP) model is convenient for examining this problem, particularly given the flexibility of Version 2 FORPLAN for representing alternative investment decision variables. Unlike the static representation shown in figure 1, the model permits the specification of domestic wood supply curves for alternative time horizons.

The base case computer run of this problem will assume that the optimal solution includes at least some importation of lumber in each period of the planning horizon (top graph fig. 1). However, if all demand is met by domestic production in at least one period for the base case, another case may be run to portray the other equilbria possibilities using the price-quantity options in FORPLAN. In this case the appropriate price-quantity locus is P_{CIF} to the point of intersection with D_D, D_D to the point of intersection with D_E, and P_{FOB} for greater quantities.

Decision Variables

The decision variables, objective function, and constraints for the problem are given in table 1. There are three categories of decision variables: land use, capacity installation, and lumber importation. The latter two categories are conceptualized as special "analysis areas" to conform to the Version 2 FORPLAN input structure.

Land Use

Table 2 gives a schematic representation of the prescription and timing choices to be considered for each analysis area over the chosen planning horizon of thirty-eight years. The first part of the table gives the prescription-timing choices for the land use decision variables.

There are four vegetation categories: PCH, native vegetation, coffee, and mixed agriculture. Based on land classification by the Ministry of Agriculture, there are three long-term land capability classes: forest, coffee, and agriculture (Vernon 1959). The rate of conversion from the current land use to the long-term land capability class can be modified by specifying constraints or limiting the prescription-timing choices for a given current land use. The land use capability classification will be used to determine what alternative land uses are permitted for a given current land use.

For pine management the principal identifiers for differentiating analysis areas are: age class, site index class, stocking, harvesting system, transport distance, roading status, and ownership class. Pine management treatments are based on even-aged management with no thinnings. The timing choices permit clearcuts between seventeen and thirty years of age (table 2).

Table 1.--Linear programming lumber import substitution model.

Decision Variables

U_{ijkl}	=	existing hectares of pine age class i, yield class j, alternative use class k, managed with prescription-timing choice l
W_{jkl}	=	existing hectares of native hardwood vegetation of yield class j, alternative land use class k, managed with prescription-timing choice l
X_{jkl}	=	existing hectares of coffee (same subscript definitions as above)
Y_{jkl}	=	existing hectares of mixed agriculture land use (same subscript definitions as above)
Z_{gm}	=	volume of lumber in use class g, imported in period m
Q_{fil}	=	operating units of standard capacity of processing function f, depreciation status i, installed and depreciating with timing choice l

Objective Function

Maximize $NPV = D'_u U + D'_w W + D'_x X + D'_y Y - D'_z Z - D'_Q Q$

D_u, D_w, D_x, D_y	=	stand or crop level net present values per hectare at the start of the planning horizon (excluding capital costs in D_Q)
D_z	=	discounted CIF price plus domestic handling cost per unit volume of imported lumber
D_Q	=	discounted capital costs per unit of capacity (purchase, installation, maintenance, and salvage)

Constraints

1. Land Area

   a. Total hectares in solution equals total hectares available

   b. Prescription-timing choice assignments are consistent with management control capabilities and land use policy

2. Import Grade Lumber Demand (for each period)

   a. Imported lumber of grade g is less than or equal to lumber demand at the duty inclusive import supply price

   b. Domestic lumber production of grade g is less than or equal to lumber demand at the import supply price, exclusive of duties

   c. Domestic lumber plus imported lumber supply is greater than or equal to total lumber demand at the duty inclusive import supply price

3. Coffee Supply

   Total coffee produced in each period, both within and outside of the model area, is less than or equal to the Coffee Marketing Board quotas.

4. Lumber and Kiln-drying Capacity

   a. Installed capacity in each period is greater than or equal to the amount required for domestic lumber production

   b. Increases or decreases in installed capacity between periods are within levels consistent with capital costs per unit of capacity.

5. Financial

   Financial cash flow of the forest industry is consistent with financial commitments and funds allocated to that sector

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Table 2.--Schematic representation of prescription-timing choices (treatment codes) for base case.

First identifier	Second identifier	Third identifier	Prescription number	Period: Year:	1 1-2	2 3-4	3 5-6	4 7-8	5 9-10	6 11-14	7 15-18	8 19-22	9 23-26	10 27-30	11 31-34	12 35-38
Initial vegetation	Permissable land use	Best alternative land use			Land use decision variables											
PC	F	HF	1		CC	RP						CC/RP				
			2		CC	RP						CC	RP			
								etc.								
			3			CC	RP					CC	RP			
			4			CC	RP						CC/RP			
								etc.								
			5		NV											
			6		CC	NV										
			7			CC	NV									
								etc.								
PC	C	CO			Prescription nos. 1-4 etc.; 5; 6-7 etc. plus :											
			8		CC	RC										
			9			CC	RC									
								etc.								
PC	A	MA			Prescription nos. 1-4 etc.; 5; 6-7 etc. plus:											
			10		CC	RA										
			11			CC	RA									
								etc.								
HF	F	HF			Prescription nos. 1-7 etc. except no restriction on maximum clearcut age											
HF	C	CO			Prescription nos. 1-4 etc.; 5; 6-7 etc.; 8-9 etc. except no restriction on maximum clearcut age											
HF	A	MA			Prescription nos. 1-4 etc.; 5; 6-7 etc.; 10-11 etc. except no restriction on maximum clearcut age											
CO	F	PC			Prescription no. 5 plus:											
			12		RP						CC	RP				CC/RP
			13		AC	RP						CC/RP				
								etc.								
			14		AC	NV										
			15		AC		NV									
								etc.								
CO	C	PC			Prescription nos. 5; 12-15 etc. plus:											
			16		AC											
CO	A	MA			Prescription nos. 5; 12-15 etc. plus:											
			17		RA											
			18		AC	RA										
								etc.								
MA	F	PC			Prescription nos. 5 & 12 plus:											
			19		AA	RP						CC/RP				
			20		AA		RP					CC	RP			
								etc.								
			21		AA	NV										
			22		AA		NV									
								etc.								
MA	C	CO			Prescription nos. 5,12,19-20 etc., 21-22 etc. plus											
			23		RC											
			24		AA	RC										
								etc.								
MA	A	PC			Prescription nos. 5,12,19-20 etc., 21-22 etc. plus:											
			25		AA											

(Continued)

Table 2.--(continued).

First identifier	Second identifier	Third identifier	Prescription number	Period: Year:	1 1-2	2 3-4	3 5-6	4 7-8	5 9-10	6 11-14	7 15-18	8 19-22	9 23-26	10 27-30	11 31-34	12 35-38
Processing function	Depreciation status	Product grade			Processing and lumber importation decision variables											
SW	EC	-	26		SV											
			27			SV										
								etc.								
			28										SV			
			29										SV/IN			
SW	FC	-	30		IN									SV		
			31		IN										SV/IN	
			32			IN									SV	
			33			IN									SV	IN
			34				IN									SV
			35				IN									SV/IN
								etc.								
KD	EC	-	36		SV											
			37			SV										
								etc.								
			38								SV					
			39								SV/IN					
KD	FC	-			Prescription nos. 30-35 etc.											
-	-	NS	40		no import "treatment"											
			41		IM											
			42			IM										
			43				IM									
								etc.								
-	-	ST			Prescription nos. 40-43 etc.											
-	-	OP			Prescription nos. 40-43 etc.											

RP = site prepare and regenerate to pine
RC = site prepare and regenerate to coffee
RA = site prepare and regenerate to agriculture
CC = clearcut pine or native hardwood vegetation
NV = initiate fallow management

AC = continue coffee management
AA = continue agricultural management
IN = install processing capacity
SV = salvage depreciated capacity
IM = import lumber

PC = pine
HF = native vegetation
CO = coffee
MA = mixed agriculture

F = forestry
C = coffee
A = agriculture
SW = sawmilling
KD = kiln-drying

EC = existing capacity
FC = future capacity
NS = non-structural
ST = structural
OP = other import grade

Native vegetation management is considered as fallow management in which the only management inputs are those for supervision and protection from encroachment by other land uses. Returns from this essentially wilderness and watershed management emphasis are not considered for the base case.

Returns from coffee and mixed agriculture are based on their expected annual land rents. For coffee, land rent is determined primarily on the length of the coffee rotation and the grade of the bean, Blue Mountain or Lowland coffee. For mixed agriculture, land rent is based on the net returns from the principal crops in each management district.

For all land use prescriptions in the base case, only one conversion from one type of vegetation to another is permitted during the planning horizon. For example, conversion from pine to mixed agriculture and back to pine is not portrayed as a prescription option (fig. 2).

Capacity Installation

Capacity installation decision variables permit the addition of additional capacity as part of a domestic lumber production strategy. Identifiers are used to distinguish capacity installation "analysis areas." In addition, other identifiers are used to specify the depreciation status and capacity function. Depreciation status identifiers are existing capacity and capacity installation during the planning horizon. Capacity function categories are sawing and kiln-drying. Prescription-timing choices for each analysis are indicated by prescription numbers 26 - 30 in figure 2.

Lumber Importation

The possibility of lumber importation is portrayed using different analysis area identifiers for each of the three imported lumber product grades: non-structural (pattern stock), structural, and other prime (dimension). Prescriptions permit the importation of various combinations of these grades for any period during the planning horizon, numbers 40 - 43 in figure 2.

Objective Function

The objective function for the problem is to maximize the discounted return from the land resource and other existing assets given the existing and expected production relationships and policy constraints. The principal activities and outputs for the decision variables are given in table 3. Activities under the heading of "developed land management" apply to all land use prescriptions except for native vegetation management. These activities would normally be subject to coordinated allocation scheduling in a Version 2 FORPLAN formulation. However, the lack of spatially detailed data and the present model's use for strategic rather than operational planning eliminate this option for the base case computer run.

Using identifiers and qualifiers the per unit activity/output amounts can be varied depending upon conditions. For example, logging productivity per crew day for pine harvesting will be related to volume per hectare and per tree. For sawmilling, lumber recovery rates and sawmilling productivity per shift operating hour will depend on log small end diameter.

Common economic cost and return information will be used to input market prices and shadow price conversion factors to internally calculate economic costs and values (Squire and van der Tak 1981). For domestically produced lumber of import grade, the CIF price of the lumber plus domestic handling charges is used as the "market price" rather than the protected price reflecting duties and import restrictions. Inferior lumber grades and residues produced as by products will be valued for the base case using recent sales prices and assuming perfectly elastic demand.

Constraints

A brief explanation of the constraints for the problem is given in table 1. The second type of land constraint (no. 1b) refers to the categorization of the land base into three ownership categories in terms of forest management control: fee simple or long-term lease, current rotation lease, and private ownership.

The lumber demand constraints (no. 2) assume the existence of a government controlled pricing policy which requires domestically produced lumber of import grade to be sold for the import supply price excluding duties. This is consistent with a maximization of consumer plus producer's surplus in the presence of import duties.

Coffee supply constraints (no. 3) are necessary to assure that coffee quantities and prices are consistent with International Coffee Board quota arrangements. In recent years Jamaican production has been about 75% of its allowable quota (Marshall 1985).

The second type of lumber processing constraints (no. 4b) is to adjust for the non-integer formulation of the problem. Financial constraints (no. 5) will not be used in the base case run of the model. However, these constraints may be important given the quasi-private nature of domestic lumber production in Jamaica.

CONCLUSION

FORPLAN can be relocated to other computer systems if the system has the hardware and software required for its use. The major hurdles in relocation are compiling and linking the separate subroutines of the program and in writing the job control statements to execute the program and the amount of resources the program uses. Software requirements are MPSX linear programming package, and a general purpose FORTRAN compiler. Hardware requirements are a minimum of 2 megabytes of RAM, at least one tape drive, and sufficient disk space.

The effort to make a multiple resource planning model has made FORPLAN Version 2 flexible enough to allow

Table 3--Principal activities and outputs.

Activity or output	Units
Developed land management	
Construction, access roads	km./ha.
Construction, harvest roads	km./ha.
Upgrading, access roads	km./ha.
Upgrading, harvest roads	km./ha.
Road maintenance	km./ha./yr.
Machine hours (mh.)	
Road construction	mh./km.
Upgrading	mh./km.
Maintenance	mh./km.
Pine Management	
Silviculture, labor input (by year in the rotation)	man-days/ha.
Silviculture, management overhead	$/ha./yr.
Logging, crew-days (cd.)	cd./cu.m. logs
Logging, machine hours	mh./cd.
Logging, machine operating expenses	$/mh.
Logging, machine capital costs	$/mh.
Logging, labor expenses	$/cd.
Logging, miscellaneous expenses	$/cd.
Logging, management overhead	$/cd.
Logging, post production expenses	$/ha. harvested
Construction, planned skid trails	km./ha. harvested
Machine hours, planned skid trails	mh./km.
Log transport, cubic meter-km.	km./cu.m. logs
Post transport, # post-km.	km./post
Log transport costs	$/cu.m. - km.
Post transport costs	$/post-km.
Sawmill, shift operating hours (sh.)	sh./cu.m. logs
Sawmill, operating expenses	$/sh.
Sawmill, management overhead	$/sh.
Head office administration,	
Plantation development	$/ha. mgd.
Logging and sawmilling	$cu.m. logs
Transfer payments,	
Plantation development	$/ha. mgd.
Logging and sawmilling	$/cu.m. logs
Log volume harvested (V15IB)	cu.m./ha.
Treated posts	# / ha.
#2 and better, dressed lumber, > 10'	
Non-structural, e.g. pattern stock	nominal cu.m./ha.
Structural	nominal cu.m./ha.
Other, e.g. dimension	nominal cu.m./ha.
#2 and better, rough lumber, 6' & 8'	nominal cu.m./ha.
#3 and #4, rough lumber, random lengths	nominal cu.m./ha.
Bark	cu.m./ha.
Sawdust, chips, slabwood	cu.m./ha.
Shavings	cu.m./ha.
Other land management	
Coffee land rent	$/ha./yr.
Coffee production (by yr. of rotation)	kg. green beans/ha.
Mixed agriculture land rent	$/ha./yr.
Native vegetation protection	$/ha./yr.
Processing capacity	
Capital costs (by year from installation)	
Sawmill	$/std. hour of capacity
Kiln-drying	$/cu.m. of lumber
Standard units of capacity (by year from installation)	
Sawmill	std. hrs./std. hr. installed
Kiln-drying	cu.m./cu.m. installed
Lumber importation	
Non-Structural grades	$/nominal cu.m.
Structural grades	$/nominal cu.m.
Other grades	$/nominal cu.m.

many different matrix structures. As a natural resource planning tool the full range of its use has not yet been explored.

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Use of FORPLAN by Industry and State and Provincial Governments: Discussion Paper

Thomas R. Mitchell[1]

Abstract.--Four excellent papers were presented. Three of these dealt with innovative uses of the FORPLAN analysis system. These illustrated the flexibility of this analysis system and the difference between FORPLAN as an analysis system, and the general perception of FORPLAN as a model. One paper illustrated many wide-spread misunderstandings of the FORPLAN analysis system. Five major implications regarding FORPLAN and its use outside the Forest Service are drawn from these presentations.

I want to begin by congratulating the authors of the four papers for this session. Their papers were excellent and raise several interesting points and suggest possibilities for expanded use and support of FORPLAN in the future.

The first conclusion that can be drawn from these papers is that FORPLAN is not well understood outside the Forest Service. This is best illustrated by the paper by Lois Dellert. She discusses reasons that FORPLAN was not selected as an analysis tool for dealing with problems within British Columbia. These reasons include the differences in context between problems faced by the U.S. Forest Service versus those faced by British Columbia; the type of modeling that best fits the British Columbia situation; and the resources necessary to implement FORPLAN.

Of these three, the most valid is the third reason. FORPLAN is now fully supported on a Univac[2] computer system, while most outside the Forest Service use IBM[2] computer systems. The export of FORPLAN from Univac to an IBM system is no trivial matter and requires much technical computer support and knowledge. This is perhaps the biggest impediment to widespread use of FORPLAN and is discussed in great detail in the other three papers.

The other three papers appear to dispute the first two reasons Ms. Dellert poses for not using FORPLAN. These other papers present many varied uses for the FORPLAN analysis system. This includes research and educational purposes, applications for assisting state-wide planning, and applications for investigating alternative investment strategies for management of forested areas. Clearly, the FORPLAN analysis system can be used to build analysis models tailored to the specifics of a particular problem. Further, the size and complexity of the resulting models can be tailored to the analysis questions being addressed and the resources available for analysis. This is supported by experience within the Forest Service where some very simple models have been constructed for a Forest that cost $5.00 to $10.00 for a complete run to very complex models requiring more than $1,000.00 for a complete run of an alternative. Of the four papers presented, this is best illustrated in the paper by Mott and Peters in their discussions of tailoring a FORPLAN model to an industrial problem.

All four papers address two other problems associated with applications of the FORPLAN analysis system outside the Forest Service. The first of these is training and documentation. Documentation in terms of users guides for either version of FORPLAN are difficult to understand to the uninitiated. This problem is overcome within the Forest Service to some extent through internal training sessions and "hot-line" support provided by the Land Management Planning Unit at the Fort Collins Computer Center. For those outside the Forest Service, there have been few training sessions provided and access to the "hot-line" can be difficult to acquire.

A second, related problem, is that even with some basic FORPLAN training and a modest understanding of the analysis system, there are often specific problems that arise. These problems relate to questions of how to tailor a model to address a particular situation. This was discussed as "high level consultation" in the paper by Davis. Again, within the Forest Service, such consultation is often provided by analysts at Regional Offices and by the Land Management Planning Unit at Fort Collins. These resources are not routinely available to those outside the Forest Service. This means that some one outside the Forest Service may have to flounder through a time consuming trial and error approach to discover how to address a particular problem. This is often beyond the resources of such users, however.

A reading of the papers leads to five conclusions that appear valid in light of experience gained by many users over the past 6 years:

1. FORPLAN, as an analysis system, can be a very useful tool for building an analysis model to address a wide variety of problems. Such models can be tailored to the specifics of a situation and the resources at hand. Often, use of FORPLAN

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[2]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

is a superior way to approach resolution of analysis problems.

2. Export of the FORPLAN analysis system to other computer systems presents a major barrier to its use. Those that have exported it have commented on the difficulty and complexity of this task.

3. Another major barrier to applications outside the Forest Service is the quality of documentation in terms of users guides and the lack of available training sessions.

4. If problems of exporting the system, documentation and training were overcome, there still appears to be a need for "high level consultation" where those most experienced with FORPLAN can help users resolve specific problems.

5. To those who have never built a FORPLAN model or used it for analysis, FORPLAN appears to be very complex, unwieldy and not capable of dealing with problems outside of National Forest Planning. For those who have experience with FORPLAN, the perception is just the opposite with almost unlimited list of possible applications.

Implications that can be drawn from these conclusions begin with an assertion that through the combined efforts of K. Norman Johnson and the Forest Service, a very powerful analysis system has been developed. It could be of benefit to States, University programs of teaching and research, consultants, and private companies. Before the full benefits of this system can be realized, though, the problems identified in the five conclusions must be overcome. These are not insurmountable problems. The question at this point, though, is: Is there anyone with the knowledge, authority and resources to overcome these problems on a wide enough scale to be of general benefit? The FORPLAN users network suggested by Larry Davis may be a move toward that end but does not appear to be a complete answer. Another suggestion is that this could be the responsibility of the Forest Service, perhaps through a restructuring and enlargement of the charter for the Land Management Planning Unit at Fort Collins. Implications and the propriety of such a move would have to be carefully investigated before such a move could be initiated.

In summary, there appears a great potential for the benefits that can be derived from application of FORPLAN to applications beyond National Forest Planning as illustrated in the papers presented in this session. There are at least five impediments to this. Solutions of these are possible, but probably long term. Thus, applications outside the Forest Service will probably remain with those who have the energy and resources to overcome these impediments on their own.

Session III:

Evaluation of FORPLAN and Implications for Management and Research.

FORPLAN: An Economic Perspective

John H. Beuter and David C. Iverson[1]

Abstract.--FORPLAN is adequate for considering economic aspects of forest planning, but its application can be improved. Rather than viewing FORPLAN as a comprehensive optimizing tool, it would be better to consider it a tool kit capable of analyzing a wide range of problems in output scheduling, land and resource allocation, transportation and project planning. It might best used as the means for determining the best feasible forest management activities in a process that builds comprehensive forest plans from the bottom up. Interaction between analysts and forest-managers is necessary if plans are to be useful.

THE CONTEXT FOR FORPLAN

What Is FORPLAN?

FORPLAN is a linear programming model designed expressly for comprehensive forest planning in which interactions among forest activities and resources are to be considered. It is driven by a primary objective to maximize or minimize something, e.g. maximize present net value. The primary objective is constrained by resources available now and over time, and sub-objectives related to the use and production of forest resources, the protection of environmental values, and the preservation of long-term forest productivity. FORPLAN mathematically determines the most efficient way to achieve the specified objectives, given the resources and production possibilities available.

This paper focuses on the use of FORPLAN for national forest planning. Theoretically, FORPLAN is a means to an end, the end being an efficient allocation of resources to maximize net public benefit. The theoretical model envisioned by the laws and regulations governing national forest planning is a general equilibrium model that includes consideration of all relevant linkages, costs and values. There is a considerable gap between theory and reality because of limitations of the model, data, people who bring together information and use the model, and laws, regulations and policies that influence how the model is employed. These limitations for the two versions of FORPLAN and similar models are well documented elsewhere (e.g. Iverson and Alston 1986, Alston and Iverson 1987, Behan 1981, Chappelle 1977, Chappelle et al. 1976).

Optimal real-life solutions are not likely to be found solely by using FORPLAN. This is upsetting to technocrats who believe that mathematical solutions within an optimizing framework ought to be accepted at face value. Nobel laureate Herbert Simon calls this "mathematician's aphasia" whereby "the victim abstracts the original problem until the mathematical or computational intractabilities have been removed (and all semblance of reality is lost), solves the new simplified problem and then pretends that this was the problem he wanted to solve all along. He hopes the manager will be so dazzled by the beauty of the mathematical formulation that he will not remember that his practical operating problem has not been handled." (Simon 1977).

We wouldn't want to leave the impression that the creators and users of FORPLAN have deceived anyone about the role of FORPLAN in the planning process. Some of these people are among the most candid critics of the model and its use. If anything, it is the managers and policymakers who foster the image of FORPLAN as the great optimizer, and with good reason. Law and regulation require interdisciplinary analysis and the evaluation of alternatives as part of the planning process. The people in charge need some way to document that this has been accomplished.

The servicing of FORPLAN and the resulting piles of computer output provide documentation that interdisciplinary analysis has occurred. The solutions for several scenarios, each favoring a different resource or management emphasis, offer a feel for the range of possibilities. Each solution is optimal (efficient) given the structure of the problem.

The chance that any of the solutions is a real-life optimization of public net benefits is remote. Even if one were, we'd have no way of recognizing it, nor of making sure it was implemented as envisioned. There is no way to guarantee it would survive the vagaries of public debate and bureaucratic decisionmaking to be selected as the management plan. If selected, there is no way to guarantee it would be properly budgeted or implemented on the ground.

It is necessary to put FORPLAN itself into perspective before we can give an economic perspective of it. FORPLAN is not the global optimizer of human and

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environmental welfare that some believe it is or ought to be. It is an abstraction of reality. It is a tool for strategic planning that helps us gather our thoughts and explore tentative paths toward the achievement of our objectives. Rather than a means to an end, it is a means to a beginning, the beginning of the process of public involvement in the development of strategic plans for our national forests.

Who Needs FORPLAN?

FORPLAN is needed to meet the requirements that arose from the passage of the National Environmental Policy Act of 1969 (NEPA) (Act of January 1970; P.L. 91-190, 83 Stat. 852), the Forest and Rangeland Renewable Resources Planning Act (RPA) (Act of August 17, 1974; P.L. 93-878, 88 Stat. 476) and the National Forest Management Act of 1976 (NFMA) (Act of October 22, 1976; P.L. 94-588, 90 Stat. 2949). Professor Wilkinson covers statutory requirements in these proceedings. Without benefit of his insight as this is written, it seems that some sort of model is necessary to evaluate alternative strategies for the use, management and conservation of the national forests, whether it be FORPLAN or something else.

The need for FORPLAN rests on the presumption that it is the best available way to accomplish or at least improve some aspects of the planning process, education and communication or decisionmaking.

The Planning Process

Among other things, the planning process is required to include "a systematic, interdisciplinary approach to ensure coordination and integration of planning activities for multiple-use management." (36 CFR 219.1(b)(10)). It must include an analysis of the management situation, collection and display of data, formulation and evaluation of a reasonable range of alternatives, and documentation of the process for use in public participation and decisionmaking (36 CFR 219.5-219.7).

FORPLAN serves several purposes in the planning process. It provides some degree of standardization among national forests in the formulation of the planning problem and in the preparation, use and presentation of data and assumptions. It provides a focus for the process and a means for evaluating and comparing the long-term effects of alternative plans on resource availability and values. The advantage of FORPLAN over other models that might be used is that it was designed and has evolved explicitly to meet the technical requirements for national forest planning specified by law and regulation. It was also designed with sensitivity to the form in which resource inventory data is available on the national forests. It is unique in its capability to change management prescriptions for a given area over time, to account for contiguous land use zones within the broader planning unit, and the uniqueness of a mix of resource values for a land use zone (Iverson and Alston 1986).

Education and Communication

Perhaps its role in education and communication is the most important for FORPLAN. As a focus for planning, it is also a focus for talking about and understanding the planning process. That this symposium features FORPLAN and not the planning process is testimony to that.

A given plan for a national forest might have been selected by any number of means, including working it out on the back of an envelope. The problem faced by a national forest manager is to convince people with differing backgrounds, from professional foresters to housewives, that the plan has taken all concerns into account and is the best of all plans given the circumstances. In the past, the forestry profession was able to assert its special qualifications (expertness) in forest management and could make decisions without much explanation about the process. It was sufficient to assure the public about sustained timber yields and regulated forests while giving lip service to multiple use. Just leave the details to the professionals and trust them.

FORPLAN provides a means of opening the process and revealing the paths by which a solution is obtained. It provides a common language and structure for communication within a planning team comprised of experts in diverse aspects of forest use, management and protection. It provides a means for the team to assure the decisionmaker and the public that a thorough analysis was done: to show them the structure of the analysis, the data and assumptions, the evaluation of alternatives, and even to reveal weaknesses and omissions. Used to display a range of alternatives, FORPLAN functions as a simulator in an optimization framework. It protracts the knowledge and thoughts of the planning team in terms of proposed actions and their consequences.

A FORPLAN analysis provides a base of knowledge and a focus for negotiation. There always will be much to be learned from it and the debate it fosters about forest resource interactions, forest practices and consequences, costs and values. The highly visible structure of the analysis provides a means to pinpoint areas of disagreement and a means for testing suggested ways to improve.

It remains to be seen whether we're any better off because of improved education and communication among interest groups, but FORPLAN should help increase respect for the expertness of the planners and managers of the national forests. As Simon (1977) puts it: "We choose among experts by forcing the experts to disclose how they reached their conclusions, what reasoning they employed, what evidence they relied upon. Having made this disclosure, they have exposed their assumptions and reasoning to the scrutiny and challenge of other experts....we [all us experts, including the man on the street] are quite prepared to examine and judge for ourselves those tenuous paths of common-sense dialectic that commonly connect a specialized fact with a general consequence in the real world. We can do this if the paths are revealed."

Decisionmaking

Will FORPLAN lead to better decisions? Again, there is no way of knowing. The decisions made with FORPLAN might be the same ones made without it. The reasons to expect FORPLAN to lead to better decisions are imbedded in the likelihood that it has helped improve the planning process, education and communication. Informed decisions are likely to be better than ones made in ignorance of data, assumptions, processes and consequences. The theories of both our democratic form of government and our free-market economy are founded on an ideal of "perfect knowledge" or at least open access to all the information available.

FORPLAN may not yield solutions that are optimum in the real world--it doesn't have to. It just has to contribute effectively to decisions that are acceptable across the interested political spectrum. It must be perceived that these decisions provide at least as much net social benefit as ones that could have resulted from other analyses. What the public lacks in understanding has to be covered by their trust in the planners and the process. Economic efficiency is an important criterion for judging both.

ECONOMIC EXPECTATIONS FOR FORPLAN

To an economist, the ideal forest planning model should be capable of maximizing net social welfare or net public benefits (Iverson 1985, Bowes and Krutilla 1986). The model should include production possibilities for all goods and services from the forest (the production surface), an objective function hyperplane that reflects expected net prices or values of goods and services, some means for handling desires that aren't accounted for in market prices or imputed values, and the capability of finding the point of tangency between the objective hyperplane and the production surface that maximizes net public benefit. That essentially describes FORPLAN, and why shouldn't it? FORPLAN was designed with the ideal in mind, to approach it, if not reach it. This leads to certain economic expectations for forest plans derived from FORPLAN analyses.

Social Welfare

The concept of maximizing net public benefits (NPB) doesn't differ much from the direction given to Gifford Pinchot in 1905 by Secretary of Agriculture James Wilson that "...where conflicting interests must be reconciled, the questions will always be decided from the standpoint of the greatest good for the greatest number in the long run." (USDA Forest Service 1983). By focusing on the greatest good alone ("net" good, that is), the maximization of NPB gets away from the impossible task of reconciling "greatest good" and "greatest number." The economist's ideal model takes care of the "long run" by discounting. In practice, law and regulation override simple discounting by imposing constraints such as those to insure reforestation and sustained timber yields.

Just as FORPLAN is only an approximation of the ideal model, its solutions are at best only an approximation of maximum social welfare. Social welfare is represented to the extent that it is possible to reflect in FORPLAN objectives and constraints the needs and wants of society, now and in the future, and all the interrelationships among production possibilities and competing demands for the goods and services from the forest. The use of harvest flow constraints to meet the needs of local industry and foster community stability is an example of moving FORPLAN solutions toward what some would consider greater social welfare as defined by Forest Service policy. If this isn't truly a move in that direction, you can't blame FORPLAN--it is only following orders.

Supply and Demand

An ideal model would distill all that is known about markets and seek an efficient allocation of factors of production to meet demands for goods and services from the forest. Setting aside the more ethereal aspects of what forests contribute to social welfare, the forest can be viewed as a factory capable of producing a wide range of marketable goods and services, jointly (multiple use) and separately (dominant use). For a fixed land base and without consideration of a labor constraint, there are three classes of production factors to consider: inherent (e.g. soil), accumulated (e.g. growing stock), and, recruited (e.g. marginal investments in such as roads and stocking control). The expectation is that resources would be allocated such that the marginal cost of the the last unit of production would equal the marginal revenue to be received. The expectation value of the soil will be maximized. Appreciating assets, such as timber, would be retained as long as their marginal value increment exceeds their marginal opportunity costs associated with other (non-timber) uses of the land and the net cash revenue from harvesting the timber. Marginal forestry investments should yield a satisfactory rate of return.

Joint production of resources (e.g. timber and wildlife or timber and water) would be accounted for in terms of the joint costs of production and relative resource values. For example, it may be economically efficient to cut rapidly growing timber in favor of increasing elk herds or water flows, even if the revenue from the timber harvest doesn't cover the cost of selling and removing it. That is, a below-cost timber sale may be the least-cost way of meeting a wildlife or water objective (demand).

The ideal model would easily make such trade-offs in terms of relative values and costs over time. In real life, the trade-offs are more likely to be imposed by prior analysis such as the exogenous determination of economic suitability for timberland, or set-asides for spotted owls based on biological rather than economic criteria, or by constraints in the FORPLAN analysis that set prescribed production levels for the various resources in each time period. There is little assurance that economic expectations can be met. Again, the model does what it is told to do.

Forest Operations

Some people expect the results of the planning process to translate to economically efficient practices on the ground. That is, the solutions should lead to the production of a desired mix of goods and services at minimum cost. Or, they should provide the maximum output of desired goods and services for a given budget.

It seems remote that even the ideal forest-wide planning model could have much relevance at the project level if it is employed from the top down and constrained by exogenously determined demands and requirements. Even if the production possibilities in the model accurately reflect local marginal costs (which they don't in real life), local unit managers could be forced into money-losing (negative cash flow) operations by production quotas imposed by the plan. For example, the plan might set aside high productivity timberland for aesthetics and force local timber operations onto lower productivity land to meet timber production quotas. Or, the amount of the timber quota itself might force local timber production up to where marginal cost exceeds market price. This is not necessarily bad in the broader context of forest planning, but can result in criticism of apparently uneconomic forestry practices, as in some below-cost timber sales.

Forest Planning

It is common to hear how expensive the national forest planning process is and how much it costs to make FORPLAN runs. The planning process is not unlike a military operation where effectiveness has considerably more weight than efficiency. Regardless of what it costs to run the model, the same questions need to be answered. The same information has to be gathered. The interdisciplinary team has to be paid.

The planning process is expensive and cumbersome, FORPLAN runs are expensive and, probably too many are being made, some of which are overly complicated. So what?

It is hard to think of projects outside of the Defense Department or NASA that have involved the complexity of post-RPA Act national forest planning. This is the first pass at it. The development of FORPLAN and the planning process is simultaneously research and operations. It would be surprising if it weren't expensive. Having come this far in the development of FORPLAN and the planning process, the priority for now is effectiveness. Efficiency will have a higher priority later.

DISECONOMIES AND OTHER PROBLEMS WITH FORPLAN, THE PLANNING PROCESS, OR BOTH

It is hard at times to figure out whether the planning process drives FORPLAN, or FORPLAN drives the planning process. In the last section we looked at economic expectations people might have for FORPLAN. They could just as well have been expectations for the planning process.

"Policy is enunciated in rhetoric; it is realized in action." Paraphrasing this opening sentence in Kaufman's (1967) classic study of the administration of the Forest Service, we might say "Forest plans are enunciated in FORPLAN; they are realized in action." Considering all the attention being paid to FORPLAN in recent publications and this symposium, one might wonder if we haven't lost track of what we are trying to accomplish. The tone set by Kaufman may be the same one we ought to have for our evaluation of FORPLAN and the planning process: In public forestry, nothing much matters if we are screwing up on the ground and in the halls of Congress.

It is easy for quantitative economists to get caught up in the eloquence of mathematical modeling and, as noted in the quote from Simon, lose track of reality. Consider the evolution of FORPLAN (Iverson and Alston 1986)--from Timber RAM to MUSYC to FORPLAN, Version 1 to FORPLAN, Version 2. Each innovation aimed at making the model more realistic, more suited to the particular aspects of forest planning and management, more sensitive to limitations in the availability and form of data, and the desire for output. As it evolved in search of the elusive optimum optimorum, the model improved for some purposes while retaining its capability to do what was useful in the past, i.e. it got more complicated. In discussing innovations in Version 2 FORPLAN, Iverson and Alston (1986) quote FORPLAN's principal author, K. Norman Johnson, as saying that the new forest activity scheduling choices are "time-consuming to construct and require considerable imagination." Referring to the same innovations, environmental writer Randal O'Toole is quoted as saying they will lead to complication at the level of "total unintelligibility."

From the perspective of the model-builder (Johnson), the model is improving, but getting harder to use. To a critic and public observer of forest planning (O'Toole), the added complication will just make it harder for him and his constituents to understand what is going on. We are faced with the prospect that we have a better model that is making life harder for the forest planners and the public, and it's not yet clear it is leading to better forest plans. How does this make us any better off?

Again, the problem is with expectations: Expectations for optimization, for social and economic efficiency, at all levels, for everyone; expectations that everything will fit together in a logical way, and that forest plans will translate easily into budget requests and on-the-ground implementation.

Links Between Forest Planning, the RPA Program, and the Budget

Recently, the Forest Service presented its latest 5-year RPA program to the Congress. It called for increasing the annual timber harvest from the national forests from 11.4 billion board feet now to between 15.6 to 20 billion board feet over the next 45 years. "I don't know what the hell we're doing, if you want to know the truth," said Representative Leon Panetta of California as he questioned how the RPA program meshed with 125 separate forest

plans (Portland Oregonian, 9/24/86). His reaction was not surprising, given that the plans from some of the largest timber-producing forests in the nation have yet to be issued, and the forecast is that allowable cuts for some of those forests will decline significantly. How then can the RPA program project a significant increase in national forest harvest?

The RPA program is the basis for requests to Congress for budgets to carry out the management plans on the national forests. It is logical that there should be some link between the forest plans, the RPA program and budgets. But there isn't--at least not any direct link that is apparent now.

The problem may be timing. The Forest Service is required to prepare a program each 5 years to help the Congress in budgeting. The 1985 RPA program was presented almost two years late, perhaps because it was awaiting completion of forest plans that themselves are long overdue. Presumably, the timing can be worked out over time; but there are other reasons to suspect that links between planning and the budget will not be easily achieved.

The Congressional budgeting process is functional in nature, focusing on about 90 line items such as timber, recreation, wildlife, range, etc. Planning involves coordination among interdependent resources such as water and timber, recreation and grazing, or other combinations involving a multitude of resource interactions. There is no easy way to translate costs associated with an integrated resource plan into functional budget categories.

At the other end of the spectrum, forest plans are developed without budget constraints so the "optimality" achieved assumes the availability of funds needed to implement the plan, and in whatever functional areas they are needed. Furthermore, it is likely that forest plans do not reflect the true cost of the activities they portray. The costs used in the plans are usually based on broad averages and don't reflect site-specific circumstances under which the plans eventually will have to be implemented. The costs are based on past experience that includes costs hidden in timber sale contracts (trading timber for services) that are not reflected in current Forest Service budgets (Beuter 1985). They also may represent local conditions and bidding practices that reflect a world that no longer exists or is less likely to exist in the future. The point is that the plans are not likely related to prevailing budget levels, and that budgets developed from the forest plans may not represent the amounts needed to implement the plans.

Then there is the matter of exogenously developed quotas that may be imposed upon forests in the planning process. What if Congress were to buy the proposed 1985 RPA program and fund an annual timber sale program of, say, 17 billion board feet, while the current forest plans reflect optimality at, say, 11 billion board feet? In effect, this would be a clash of optimalities. If we believe the RPA program analysis, public net benefits will be maximized by higher harvests from the national forests to meet expected increases in the demand for timber (presumably by holding down consumer prices). It is presumed to be technically possible to achieve the increases without compromising environmental and non-timber resource values. But the lower harvest levels prescribed by the forest plans are largely because of the need to protect environmental and non-timber resource values.

There appears to be incompatibility between the RPA program analysis and the forest planning analyses, either in timber production possibilities or constraints related to other resources and environmental values. Congressman Weaver may be correct when he asserts that increased timber harvesting would come at the expense of wilderness and wildlife values (Portland Oregonian, 9/24/86).

Links Between Forest Plans and Forest Operations

FORPLAN, Version 2 provides the capability to consider site-specific management on the national forests. It is possible to consider unique resource interactions and values within specified zones, and have timber harvest and other resource outputs allocated specifically to that zone as a result of optimizing the objective function. Doing so provides useful information about the priorities for specific areas, e.g. watersheds, in the achievement of an optimum plan for the forest. Unfortunately, what appears optimum for the forest may not be optimum for a watershed.

It is in this consideration that one may get queasy about the use of linear programming for large-scale forest planning. The problems involved in the classic uses of large-scale LP models in the chemical, petroleum, railroad and communication industries, the Department of Defense, NASA, and even agriculture just aren't the same as the problems involved in large-scale forest management. It isn't just a matter of scheduling machines, transportation routes, boxcar loading, cracking plant capacity, or how many acres to devote to wheat, corn and milo.

Sub-areas of a forest are dynamic ecosystems, almost any of which can be considered unique in some way. Because of some characteristics, they are not interchangeable. For example, timber in one drainage is not the same as timber in another drainage. Although stands may have similar structure and characteristics, their unique location and relationship to surrounding plant, animal and human communities may give them special values or costs.

None of this is news; and we don't mean to imply that there is insensitivity to it in national forest planning. Version 2 FORPLAN was developed to help account for site uniqueness. The problem arises because the major focus of forest planning is the annual allowable timber sale quantity (allowable cut). Timber harvesting and related road construction and development drastically change things on the forest. The allowable cut is a highly visible and politically volatile standard against which to measure forest performance. Once announced, there is much pressure to get out the cut and maintain it.

Linear programming is very well suited to timber harvest scheduling, *per se*. But, despite the existence of allocation choices and zones, the FORPLAN allowable cut is only a tentative one based on the planning assumptions about economic and environmental suitability of land for timber production, roading costs, logging costs, timber quality, and revenues. In the past, precise knowledge about stand or area operability was not a major concern because there were many options for where the allowable cut might

come from within a ten year period. If a proposed sale area was found to be a problem, that area could be set aside and another selected. On the western national forests, a considerable error associated with the tentative allowable cut might not even be noticed because it could be absorbed into the cushion provided by the backlog of overmature timber.

As the backlog of old-growth diminishes and concerns increase about the environmental and economic circumstances of individual timber sales, the cushion for absorbing errors is disappearing. The objectives and consequences of harvesting must be better thought out today than in the good old days when it was sufficient to justify the timber sales program only based on converting overmature, slow-growing stands to young, thrifty stands. Not only is there concern about environmental effects, but increasing scrutiny of the economic effects. In the past, the planned allowable cut could be (and was) viewed as God-given and carried out without further question. From now on, planned allowable cuts will more likely be viewed as tentative, pending site-specific analysis and verification.

The link between operational feasibility and forest plans is tenuous despite the improvements in Version 2. The allowable cut allocations of the forest plan might be changed considerably by site-specific (project) analysis, sometimes increased, sometimes decreased, depending on local concerns. Ryberg and Gilbert (1986) have shown how site-specific (zone) FORPLAN optimization could increase the allowable cut and present net value for the zone (from negative to positive) compared with the allocation from the forest-wide plan, while decreasing anticipated road construction and meeting environmental constraints. One has to wonder why the planning analysis isn't built from the ground up in the first place, starting where the plan is to be realized--where the action is.

The Link Between Forest Planning and the Outside World

We have discussed planning links upward to the budgeting process and downward to specific sites on the forest. The consideration here is the link outward to the rest of the world.

The incongruity between the RPA program and forest plans is at least matched by the incongruity between the forest plans and what is going on outside the national forests. Exception for harvest flow constraints aimed at controlling prices for wood products or the flow of timber to dependent communities, there has been little effort to develop national forest plans with sensitivity for the management of surrounding lands in other public and private ownership, nor the social and economic impacts that might derive from the the plans. Such considerations may be trivial for many of the 125 or so national forest planning units, but they are an important consideration for the heavily timbered forests of the Pacific Northwest. They also may be important where commercial development for recreation, water, livestock, and minerals are possibilities. Again, problems arise because of the expectations for optimal solutions. How can we possibly be optimizing net public benefit if planning for the national forests is done in a vacuum?

That isn't to say that the Forest Service is insensitive to this issue. Broad-scale economic impacts are considered in the development of the RPA program. With consideration for local economies, departures from non-declining even flow have been included among planning alternatives on some national forests to at least test for their possibility and show their effect on other national forest resources. Some forests are responding to public concerns about the effects of planning alternatives on local economies.

But there is no report of forest plans being developed by including in the FORPLAN analysis the situation and production possibilities for timberland outside the national forests. Because of this, Oregon is preparing to respond to the upcoming national forest plans with its own analysis of more comprehensive production possibilities including all timberland ownerships (Johnson and Greber 1986). This study will show the possibilities for modulating national forest timber harvest schedules while preserving at least the same concern for environmental and non-timber resources as included in the national forest plans. The objective is to find how Oregon might maximize its net public benefit form all the timberland in the state.

THE ECONOMIC ADEQUACY OF FORPLAN

FORPLAN provides a means to find efficient solutions to well-defined forest resource allocation problems. Whether the solutions are economically adequate depends on the structure of the problem FORPLAN is asked to solve. Some problems may lack economic considerations, e.g. timber volume maximization problems constrained only by physical and biological relationships. Other problems may appear to focus on economics, e.g. maximize present net worth, but because of non-economic constraint the solutions have little to do with economic efficiency. It is possible to set up analyses aimed at economic efficiency, e.g. ones that maximize present net worth or internal rate of return with a model structure that permits the selection of activities at the margin of economic efficiency, subject to meeting minimal legal and institutional constraints.

The economic adequacy of FORPLAN may have more to do with how it is used compared with expectations about economic efficiency than it does with the model itself. Exogenously determined constraints can cause the exclusion from the plan of economically efficient production possibilities, or the inclusion of uneconomic ones. The latter is what happens when a forest plan includes below-cost timber sales and uneconomic forestry investments. The Forest Service defends these apparently uneconomic activities in terms of indirect benefits such as vegetation management for wildlife habitat, aesthetics, forest protection, recreational use of roads, forest development and community stability (USDA Forest Service 1984).

Unfortunately, these benefits are hard to pin down. It is not usually evident that investments with negative cash flows, such as below-cost timber sales and advance roading, are the least-cost way of achieving these indirect benefits.

In remanding the forest plan for the San Juan National Forest, the Secretary of Agriculture asked the Forest Service:

> "Is the timber program as currently proposed actually the most cost effective way to achieve the non-timber multiple use objectives of the plan?...To what extent can the timber program costs be cut and/or revenues be enhanced while still providing an appropriate level of non-timber multiple use objectives?" (July 31, 1985).

To answer these questions, the forest must look at alternative production possibilities for achieving forest objectives, presumably ones that were not included in the original FORPLAN analysis. The implications are that there might be cheaper ways to achieve non-timber resource objectives than to make below-cost timber sales. At least the plan should be convincing in the need for such sales to achieve non-timber objectives.

Bowes and Krutilla (1986) show how FORPLAN can be used to analyze the separable costs of joint forest outputs such as timber and water. To do so, the analyst must know the least cost way of achieving the separate resource objectives--exactly the information the Secretary is asking about for the San Juan National Forest. Through successive FORPLAN analyses eliminating one resource at a time, it is possible to determine the incremental (separable) cost associated with the planned output level for each resource. Such an analysis may or may not prove the assertion that a below-cost timber sale program is justified by non-timber benefits; but it would have much more credibility than the current plans in which the public is expected to take it for granted that money-losing timber sales increase net public benefits. As an appellant of a forest plan recently put it: "Why jeopardize fish habitat and risk wildlife loss with timber sales that lose money for the government?" With all the time and effort that has gone into the plans, it is hoped the Forest Service can provide a good answer.

The economic relevance of FORPLAN analyses also is affected by specific assumptions about prices, costs, values, and production possibilities. O'Toole (1986) argues that many forest plans are not on the true production possibility frontier because of the use of high timber price trends that delay harvest in the early periods to take advantage of higher prices in later periods. None of this is the fault of FORPLAN.

In December 1979 the Forest Service adopted FORPLAN as the required analysis tool for forest planning (Iverson and Alston 1986). With benefit of hindsight, this decision may have had the good intentions of settling on a consistent way among forests to maximize public net benefits, but the FORPLAN adopted (Version 1) was little more than a sophisticated means for timber harvest scheduling that "was bound to fail as a universally applicable model because it simply was incapable of...[providing] meaningful answers [about] what would happen and where it would occur as a result of the forest plan in the next 10 years." (Iverson and Alston 1986, quoting K. Norman Johnson).

Given the state of knowledge at the time FORPLAN was adopted, it is not surprising that many people had inflated expectations for what it would do. However, even with the improvements since then, it is still not the universal and complete planning model that some believe we need. It never will be.

It is debatable whether it even should be used for large-scale, forest-level planning, at least not with the level of sophistication now used. Version 2 may be best suited to site-specific project analysis involving coordination between forest development and resource use and production, and timing choices.

We should not overlook the realities that govern what will happen on the national forests. Allocations for wilderness, the preservation of old-growth timber, riparian zones, and other sensitive resource issues are likely to be made outside the forest planning process, and enter into the process as constraints or reductions in land and resource availability.

Budgets for national forest management will be carried along by momentum from past political acceptability, including some amount off-budget discretion associated with timber sales. The timber sale program will always dominate the budget justification because of the size of its budget, its importance for local economies, the amount of Forest Service employment and activity associated with it, and the perception that it makes money for the U.S. Treasury. For heavily timbered forests having prospects for growing timber economically, there will be pressure to maximize the allowable cut, subject to meeting the minimum requirements for environmental protection and non-timber resources.

For forests that have established timber programs, but on which timber production is a questionable economic venture, the pressure will continue to justify the timber program in terms of what it contributes to the production of other resources, the protection of other values or community stability.

What is the role of FORPLAN in this? It is a valid means to evaluate alternatives at the project level and above, and to determine allowable cuts while accounting for environmental concerns and other constraints. It provides a structure that is useful for communication and education, and as a means to test "what if" questions.

There is little doubt that the role of FORPLAN in the planning process needs to be refined to increase both effectiveness and efficiency (see Barber 1986). It may be much better suited to site-specific project analysis, such as for a watershed, than it is to large-scale, forest-level analysis. It may be better to employ FORPLAN at the project level and build the forest plans up from site-specific analyses, rather than trying to develop forest-wide optima that may translate into site-specific problems.

FORPLAN is a significant accomplishment as a tool for planning forest management activities. It is serving an important role as the focus for thinking about comprehensive, interdisciplinary planning, and for education and communication about forest plans. It probably has done more for educating people, foresters, and others, about the complexity of the of multiple use forest management planning than it is done for solving the problem of getting out the plans.

Yet, what credibility would the plans have without FORPLAN analyses?

If not FORPLAN, what?

EPILOGUE

A forest planning system such as FORPLAN can be evaluated in at least two ways. An evaluation of interest mainly to model builders and operations research theorists focuses on a generic matrix generation package that can be linked to a solution algorithm designed to solve a specific mathematical programming problem.

A second type of evaluation focuses on the results from the application of the system and is more of interest to forest managers, the Congress, and groups with special interests in forest planning. The following comments address both types of evaluation, though it is too early to thoroughly evaluate the the results of applying FORPLAN to forest planning.

The development of FORPLAN reflects a "maximizing" strategy rather than an "optimizing" one. FORPLAN is more a tool kit than a tool. Much like a PAC MAN, FORPLAN has gobbled up several systems designed to solve specific problems in output scheduling, land and resource allocation, transportation planning project planning, and combinations thereof. Unlike PAC MAN, however, FORPLAN has retained intact the systems it gobbled up, thereby allowing users to analyze problems from varied perspectives.

The multiple model framework of Version 2 contains elements of Timber RAM, ADVENT, IRPM, RAA and others. From a researcher's standpoint, it provides a means to evaluate various paths of analysis for a variety of natural resource management problems. Whether it's of use from a manager's standpoint depends on whether the results have any practical application. Can they be implemented on the ground? Can they be used to justify budget requests?

Successful use of FORPLAN to solve planning problems and meet the needs of practitioners in forest management requires investment in several key areas. System software support, training of analysts, and consultation with users are all needed to assure thoughtful and efficient use of the system. Management analysts must be carefully selected for their ability to shift between the complexity of FORPLAN and the technical, social and political complexities of day-to-day forest management. FORPLAN can sort out mathematically infeasible solutions, but is incapable of recognizing ones that aren't feasible in real life. It takes interaction with real forest managers with names such as MARVIN to avoid those kinds of infeasibility.

Stressing the human aspects of planning should not be construed as rejection of any analytical system, whether large mathematical model or otherwise. The point is: the system is not the solution; people are. Long-range planning is nothing more or less than risk-taking decisionmaking. If we don't give any thought to where we are going, any road will get us there--and without planning, there's a good chance we won't like where we've arrived.

The role of planning analysts is to aid the thought process. There must be interaction between analysts and managers. True optimization will occur if there is agreement on the problems to be analyzed and it turns out the results of the planning process are meaningful and useful.

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Discussion of FORPLAN: An Economic Perspective

John Hof[1]

Abstract.--Linear programming (FORPLAN) is evaluated as an applied economic efficiency tool: activity analysis is contrasted with a production function, spatial considerations are discussed, the need for an acre-by-acre solution is evaluated, and the problem of response discontinuities are analyzed. The linkage between FORPLAN and regional and national planning is also discussed.

The paper by Beuter and Iverson (1987) provides a good overview of the economic content and usefulness of FORPLAN. I will try to expand upon their paper in two broad areas: further evaluation of linear programming as an applied economic efficiency tool, and the linkage between FORPLAN (the forest planning effort) and RPA (higher level planning). The selection of these two areas and my remarks about them reflects my own experience, interests, and on-going personal research topics.

Linear Programming as an Economic Model

FORPLAN is a matrix generator and a report writer linked to a linear programming solution package. A diligent, creative analyst can do almost anything with any version of FORPLAN that can be done with a linear program. An evaluation of FORPLAN is, therefore, an evaluation of linear programming--or at least the type of linear program that has been used (with or without FORPLAN) in timber harvest scheduling and forest resource allocation models. Therefore, linear programming (LP) will generally be referred to hereafter, rather than FORPLAN.

Activity Analysis Versus a Production Function.

Economic analysis of a production process, such as that encountered in managing a forest ecosystem, generally starts with a production function. This is a function, not generally observable, that relates inputs (factors of production) to outputs (the things being produced). The production function is defined to show "technically efficient" output levels given the inputs. If only one output is involved, this means that the production function will show the maximum output possible for a set of inputs. If more than one output is involved, the production function will indicate a set of output possibilities such that no more of any one output could possibly be produced without an ancillary reduction of some other output or outputs, given any set of inputs. The use of the production function assumes that the engineering problem of determining physical production technology has been solved and the economic analysis proceeds from there.

As Herfindahl and Kneese (1974) state:

> "...we must now recognize that in something as complicated as many natural resource management systems, the engineer cannot be expected to supply the economic analyst with a production function...Even a simple problem involves a huge number of alternatives...Thus, water resource planning presents a complex and difficult problem of design which in practice does not allow the neat separation of technological and economic factors implied by the production function analysis." pp. 281-282.

Thus, an economist would hope that an LP would be capable of solving the engineering problem of technical efficiency and the economic problem of choosing the input set and the output set that maximizes net benefits.

Because we cannot specify the production function that directly relates inputs and outputs, we have resorted to linear programming which is a type of activity analysis. By this, I mean that in an LP, inputs are clustered into packages or activities, and then the LP attempts to solve the engineering problem of technical efficiency and the economic problem of input and output selection simultaneously. It is remarkable that an LP, at least in principle, could perform such a feat.

However, if an LP is to even come close to emulating a production function, the activities--management prescriptions in FORPLAN jargon--have to include (implicitly) a variety of possible input sets, a variety of possible output sets, and somewhere in all the activities included, the technically efficient means of combining the two. It seems that this is the most fundamental assumption required to claim that an LP is achieving an economically efficient solution--that somewhere in the LP, the "correct" solution is available for the LP to select. In other words, in representing the production system with a collection of activities, the only way that a production function is likely

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to be emulated is if the activities include every possible combination of inputs that is technically feasible. Given the pragmatic limitations of any planning exercise, it is not clear that any LP represents all the relevant production possibilities. If the LP is designed to reflect only modest changes from current practice, then either we are close to being efficient already (and the planning problem is nearly trivial) or, more likely, the LP will not emulate the production function and will not be capable of approximating economically or even technically efficient solutions.

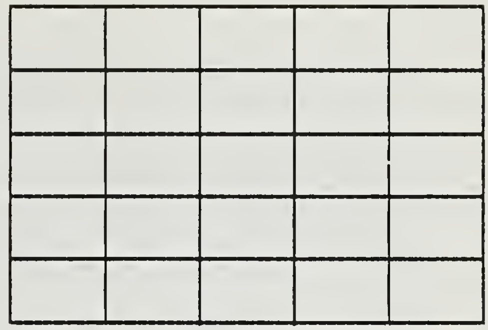

Figure 1. A square analysis area segmented into 25 parts.

Spatial Considerations--The Real Nonlinearity Problem.

The next most fundamental weakness of LP is probably its linearity. This statement should not be misunderstood. LP can be used to piece-wise approximate highly nonlinear relationships between inputs and outputs. For example, if different management prescriptions are included that involve different levels of intensity of some input's utilization, the different A-matrix coefficients under these different management prescriptions can reflect highly nonlinear responses to changing input intensity.

The linearity assumptions of an LP cause some problems, however. By far the most important of these problems is that of accounting for the impact of the spatial configuration of a management action on the outputs of interest. In terms of outputs such as water, wildlife and fish, and aesthetics, it is probably more important how a management action (for example, a timber harvest) is spatially laid out than how many acres are involved. Version 2 FORPLAN has attempted to deal with this problem by making the LP behave more like an integer program and by defining management prescriptions not on a per acre basis but applying to an entire watershed with a spatial configuration defined. This allows the prediction of the resulting outputs to take the given spatial layout into account; but a serious problem remains. Within the practical limits of the LP, only a tiny number of the possible spatial layouts can be considered. Remembering that the LP will only perform well in an economic efficiency context if all technically feasible options are included, this is not a trivial problem. An example might be useful to illustrate the point.

Imagine a rectangular watershed as depicted in figure 1. Assume that because a low level of resolution is required, we segment the watershed into 25 equal sections (fig. 1). Also assume that we only have one management action (e.g., clearcutting) to consider, versus doing nothing. Even in this very simple example, if each of the 25 sections could be clear cut or not, 2 to the 25th power or over 33 million spatial configurations are possible. With more potential management actions or with finer resolution, the number of spatial possibilities approaches google numbers very rapidly. Add the scheduling problem (dynamic considerations) and the problem defies conceptualization.

If, however, management prescriptions were based on a per acre basis, the LP determines at least the number of acres to which each management prescription applies. The problem is, the (nonlinear) response to different sizes and shapes of the management action is lost in a fixed per-acre production coefficient. The magnitude of this problem should not be minimized. The spatial considerations are so important that most of the forest outputs cannot be determined with any reliability at all on a per acre basis. Also, we simply have no means to analyze a reasonable representation of the spatial options that are typically available.

The Need for the Acre-by-Acre LP Solution.

The previous two sections should provide a feel for just how ambitious the task is that FORPLAN models have apparently been intended to accomplish. The FORPLAN model is being asked to solve the engineering problem and the economic problem previously defined for a very complicated production system that includes spatial and temporal placement of management actions on an acre-by-acre basis. The futility of accomplishing this task with a high degree of precision appears to be the theme (and it's a good one) of the Beuter and Iverson paper.

I cannot resist going one step further and ask if this is really necessary. Is the purpose of the forest planning analysis (FORPLAN) to provide a management plan, *per se*, or to provide guidelines in the development of a management plan? The answer might be found as the forests move into the implementation phase of the planning process. If the detailed solution of the FORPLAN models is never really used in implementation of the plan, then it could be argued that it was never necessary. Even if the detailed solution of the FORPLAN models is used, it is not clear that enough of the spatial considerations have been accounted for to make the detailed FORPLAN solutions truly useful in implementation. A more stylized approach oriented towards guidelines rather than detailed global optimization might have accomplished as much or more.

It also might be useful to point out that some models encountered in optimal control and dynamic programming approaches yield decision rules rather than numeric optimal solutions to the choice variables. Although they are more qualitative, these decision rules might be more broadly applicable and more in the spirit of a planning analysis than a detailed quantitative optimal solution. I emphasize that I am only intending to raise questions here; this is discussion not proposal.

Discontinuities

My final comments on LP as an economic tool emanate from the very commonly expressed concerns that LP does not seem to be very effective in dealing with phenomena such as fire, insect and disease infestations, or other dramatic ecological changes. I believe that it is not uncommon for this shortcoming to be attributed to the fact that LP does not incorporate stochastic variation in the response variables with great ease. I also have heard it suggested that LP fails because it does not easily incorporate risk averse perspectives or that it does not account for the desirability of flexibility or the undesirability of irreversible decisions.

All these points are well taken; however, all these weaknesses could be remedied and the LP still would not perform well in terms of modeling things such as fire, insect and disease infestation, etc. My reasoning is as follows. An LP is based on a calculus-oriented formulation of the optimization problem at hand, where constraints and objective functions are smooth, many-times differentiable functions. That is, the basic mathematical foundation of an LP includes an assumption that small changes in choice variables will result in small changes in response variables. Likewise, symmetrical reactions to small changes in choice variables are implicitly assumed.

Phenomena such as fire and insect and disease infestation simply don't behave that way. They behave in fits and starts and at times very small changes in choice variables can cause an immense impact on the ecosystem because of such a discontinuity. I would assert that managing these unstable "catastrophes" is generally more important than managing the ecosystem when it is "well-behaved." I would also assert that we are more likely to learn fundamentally new things about the ecosystem by concentrating on the discontinuities than we are from studying the smooth, slow changing behavior that an LP can handle.

Refocusing our analytical energy on the discontinuities should not be taken lightly or undertaken prematurely. It will require moving into an entirely different area of mathematical analysis. A new branch of applied mathematics called "Catastrophe Theory" has developed out of topology and may show promise in this area. Many questions remain unanswered. A very large part of my research focus over the next 5 years is planned to be in this pursuit. Many researchers around the country are working on Catastrophe Theory, and the potential is very exiting. At this point, however, this work still belongs on the desk of the researcher and is not ready for a planning analysis such as that in forest planning.

Linkage Between FORPLAN and RPA

Beuter and Iverson state:

"It is logical that there should be some link between the forest plans, the RPA program and budgets, but there isn't--at least not any direct link that is apparent at the present time"

I doubt that there will be very much disagreement that this linkage is logical. Also, I believe it is the intent of the agency to accomplish as much of a linkage between forest planning and RPA as is possible in the development of the 1990 Program. Part of the analysis of resource interactions for the 1989 Assessment will be based on the alternatives generated with the FORPLAN models (Hof and Pickens 1986). The approach to be taken focuses the regional/national analysis on the selection of discrete management alternatives provided (perhaps over a period of years) by the forests (see Wong, 1980; Bartlett, 1974). These discrete alternatives will include scheduled outputs and costs. They, in essence, will be zero-one choice variables in higher level models that could be linear programs or integer programs. A test of this approach is reported in Hof and Pickens (1986, 1987).

This test shows that the Bartlett-Wong approach performs very well in terms of overall optimality--it is able to locate "points" on the global production possibilities frontier with a high degree of accuracy. The Bartlett-Wong approach, however, does not closely emulate a global optimization in terms of forest level output solution values or budget allocations across forests. It is thus much more useful for Assessment analyses than for Program analyses. Given the above-quoted viewpoint that the forest plans and the Program need to be linked, however, this multilevel model may be useful in the Program as well.

It should be emphasized that if forest planning alternatives are to be used in building the Program alternatives (regardless of the method), then a systematically varied set of forest alternatives would be most useful. Beuter and Iverson state:

"...FORPLAN runs are expensive and, probably too many are being made..."

If forest planning information is to be used at a higher level of planning, then I would take serious issue with this statement. In this context, the purpose of forest planning is not just the development of a "preferred alternative" but the development of a set of alternatives that effectively describe the range of options available. My reaction would be that we probably need more runs (alternatives) not fewer, and if FORPLAN is too expensive to do this then it is a very serious shortcoming. One advantage of modeling a planning problem should be that sensitivity analysis and "what if" exercises are possible. If we can't experiment with the model, its utility is greatly diminished. As an example, the performance of the Bartlett-Wong model is directly affected by the number of and systematic variation in the alternatives included.

Given these conclusions, the Forest Service might eventually consider developing the capability to pursue an approach such as that discussed by Kornai and Liptak (1965). This approach involves a game theoretic model between a higher level planning authority (the "center") and a set of sectoral planning units. The center makes an initial provisional distribution of the "available resources, material, manpower, etc. among the sectors, and at the same time also indicates their output targets." The sectors then rigorously analyze this set of quotas and report back "one type of economic efficiency index--the shadow prices derived from programming." A model such as FORPLAN

would be well suited to such an analysis. The center then modifies the resource and output quotas based on this information. By iterating back and forth, a sectoral allocation is arrived at that, within a given tolerance level, equates the shadow prices across sectors and thereby reaches a global optimum. This is a direct type of decomposition of the global optimization problem. To use a Kornai and Liptak type of model, the Forest Service would need to have all forest (FORPLAN) models operational during the same period of time, and communication channels would have to be opened to support the iterations between higher and lower levels. Until this would be possible, the Bartlett-Wong approach has the potential to address at least part of the problem and encourages the general sort of coordination that would be necessary for the Kornai and Liptak approach.

It is also important, if FORPLAN solutions are to be used in any sort of higher level analysis, that consistency between forests is maintained. This includes the definition of outputs, definition of costs, inclusion/deletion of outputs, the definition of time periods, and the definition of alternatives. In this round of planning, it would be difficult to argue that the forest plans are consistent on any of these counts.

One final remark regarding the linkage between FORPLAN and RPA might be worthwhile. Beuter and Iverson correctly assert that, "There is no easy way to translate costs associated with an integrated resource plan into functional budget categories." There is no way to tenably perform this task. Furthermore, Hof and Field (1987) showed that output level decisions based on any of the commonly used methods should be expected to be biased. It would be much more defensible if we were able to base all output level (resource allocation) decisions on joint costs and use cost allocation only for accounting purposes.

Conclusion

In conclusion, I would like to express a philosophy that the purpose of quantitative modeling is not to provide an answer, but rather to serve as a thinking tool and a device for organizing the problem at hand. If this viewpoint were to be accepted, then a model such as FORPLAN would be most useful if the decision-maker(s) were much more involved in its construction and use. If this is organizationally impossible, then perhaps this particular philosophy should be dismissed. However, if the philosophy has some intrinsic merit, then perhaps the agency should accept the challenge of bringing the analysis itself into the grasp of the decision maker.

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The Costs and Benefits of a Forest Planning Model: Discussant's Comments

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Abstract.--This paper focuses on the external economics of FORPLAN. What are the costs and benefits of this particular planning model and the process based around it? It discusses the costs and benefits of the planning system, and concludes by examining alternatives to FORPLAN

An economic perspective on FORPLAN usefully distinguishes internal from external economic questions. Internal economic questions refer to the use of economic concepts and information in the operation of FORPLAN itself. Examples include the estimation of silvicultural costs, derivation of the technical coefficients linking activities to outputs, and determination of the demand for various forest products. These problems are by no means trivial (especially the questions related to demand), but are understood reasonably well. External economics -- the costs and benefits of the planning system itself -- are the focus of this paper.

Costs

As with most problems in natural resource economics, the costs appear far more clearly than the benefits. Six kinds of costs are relevant to an evaluation of FORPLAN.

Analysis Costs

National forest planning is an unmitigated example of what Simon(1979) has called procedural rationality. He argues that the objective of procedural rationality is to find optimal decisions net of analytical costs. The costs of developing the FORPLAN system and the FORPLAN models for each national forest apparently are not known with any degree of certainty, but are thought to be several hundred million dollars. To evaluate the planning system, these costs must be calculated. Such a summary has been requested by Congress for the national Resources Planning Act Assessment and Program (RPA). A similar accounting should be made for the planning activities promulgated under the auspices of the National Forest Management Act (NFMA).

Beuter and Iverson ask if FORPLAN will lead to better decisions. Because all national forest planning relies on FORPLAN, there is no way of wholly answering this question. However, better decisions must, by definition, differ from past ones. Beuter and Iverson's question can then be partially answered by determining if FORPLAN has resulted in decisions which differ from the ones made under earlier planning systems. Little evidence has been presented on this point. Schweitzer et al. (1986) argue that current decisions probably differ little from past ones because "there are powerful forces in the forest planning process that influence most forest plans to be similar to traditional types of forest management." (p. 10). If the use of FORPLAN is not altering forest management decisions, then this costly planning procedure does not achieve Simon's desideratum for procedural rationality.

Suppose that FORPLAN represents overinvestment in analysis. What, then, is the optimal amount of analysis? The "Max-Loss" procedures developed by Navon et al. (1986) offer one approach for addressing this question. Rows and columns of the FORPLAN matrix can be aggregated, and a bound on the loss of efficiency resulting from the aggregation can be calculated. In their sample problems, the loss in efficiency was very small even with large reductions in problem size. Thus, in large FORPLAN models the marginal costs of increased complexity probably exceed the marginal benefits. Economic efficiency would be served by reducing model size.

My own, limited experience with FORPLAN suggests that the net present value surface may very flat near the optimum; many different management plans have very similar economic performance. These different management plans may have quite different political implications. Rather than simply solving every FORPLAN problem to optimality, the analytical effort would more usefully be directed towards identifying all the plans which are "nearly" optimal.

Institutional Costs

The use of FORPLAN excludes important people from the national forest planning process. That the general public cannot understand FORPLAN is by now obvious. A public excluded is a public prone to litigation. This fact results in a central paradox of applying the rational planning paradigm to the national forests: if the public

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participates effectively in the planning process, the results are necessarily politically determined; if the public is systematically excluded from the planning process, the process will be subverted by legal challenge. In either case, politics, not rational planning, determines the outcome.

FORPLAN apparently also excludes people within the Forest Service from participating in forest planning. Votyas (1986), a Deputy Forest Supervisor on the Ottawa National Forest, commented on that Forest's plan:

> Because of the speed necessary to develop and complete the Ottawa National Forest Plan,...we had to...exclude some people from the analysis process. Some district rangers and Forest staffs didn't have the time or personnel or perhaps finances to get as deeply involved as they probably should have. I'm sure some didn't have the interest or motivation or knowledge as well. Maybe some were turned off by the complexity and sophistication of the FORPLAN model...some Forest and District people were left in the dust, so to speak. They were unwilling, or unable or not permitted to keep up with the planning process. (p. 119-120)

Through this tendency for selective exclusion, the use of FORPLAN in national forest management planning inevitably affects the internal organizational structure of the Forest Service. For example, one might hypothesize that FORPLAN is a tool for the timber management interests within the Forest Service to regain some of the ground they lost during the past decade. Bits of evidence support this hypothesis. For example, in their review of the history of FORPLAN, Iverson and Alston (1986) note that FORPLAN was acceptable to the agency only because of its roots in harvest scheduling optimization. As another example, I once visited a national forest in the midst of a forest planning crunch. Their FORPLAN model was not functioning as expected, and they needed help. Who was contacted? The Timber Management Staff in the regional office!

The longer term changes in the structure of the Forest Service which have been induced by FORPLAN are likely to be rather subtle. For the researcher in organizational behavior, it might be useful to follow the careers of the planners, operations research analysts and economists hired during the first round of NFMA planning. Will they rise through the ranks to become district rangers and forest supervisors? Or will the agency's immune system isolate them?

Increased Centralization

The 1979 directive requiring all national forests to use FORPLAN shifted power upward in the classically decentralized Forest Service. Increasing the degree of central control, while tending to standardize plans, limited on-the-ground testing of alternative analytical approaches to the forest planning problem. Neither FORPLAN nor its immediate predecessors were vetted through the normal research procedures of peer review and publication. Because FORPLAN had not received the benefit of "research" in the normal "research and development" process for creating new methods, the Forest Service would have been served well by the kind of exploratory work which would have occurred on individual national forests under a less centralized planning system.

Traditionally the management plans for individual national forests have been negotiated locally among local interest groups. The exceptions have been rare and notably so: the Bitterroot and Monongahela National Forests, for example. The shift to a procedurally complicated, technically complex, standardized planning model has made the management practices on individual national forests easier targets for the powerful centralized critics--the Office of Management and Budget, and the national interest groups such as the National Forest Products Association and the Wilderness Society. The Wilderness Society has been particularly effective in using the increased centralization to its own advantage. Once the complexities of FORPLAN have been mastered, the cost of analyzing another forest plan is low. The scale economies of knowledge associated with a standardized planning process inevitably favor the national interest groups over the local ones.

Elsewhere in this symposium others have argued that FORPLAN has served to shield the Forest Service from its critics. Where the critics do not have the technical capability, time or money to master FORPLAN, perhaps this is so. But once the key to the central defense is discovered, the shield no longer serves well. A diversity of planning methods would be a better, more permanent defense, particularly from the national interest groups to whom the Forest Service is most vulnerable.

Increased Ignorance?

Mathematical models exclude some considerations so that other aspects of a problem can be treated with great clarity and precision. This systematic exclusion of information is precisely the value of quantitative approaches to management and policy analysis. Yet this characteristic also produces the risk of Beuter and Iverson's "mathematical aphasia," or what is less eloquently known as a Type III error--solving the wrong problem. During the past three decades of large-scale social science modeling, the analytical landscape has become littered with modeling efforts wrecked by failure to include some important phenomenon. What important information does FORPLAN systematically exclude?

Systematic exclusion of information in planning results in a more limited capacity to respond to future change. Because the future is inherently unknowable, some attention should be paid to "surprise rich" scenarios. By their very nature, such scenarios may be difficult to quantify: there is no historical record on which to base the conventional analyses. Data are history, but planning is about the future. Too great a reliance on quantifying the past increases, rather than reduces ignorance about the future.

Planning in a Vacuum

Beuter and Iverson emphasize my fifth point: the current forest management planning process focuses on individual national forests without consideration of adjacent lands. This inevitably results in suboptimal social solutions to forest sector problems.

The best solutions may lie outside the national forests. For example, the Pacific Northwest Forest Policy Project (Bruner and Hagenstein 1983) showed convincingly that a coordinated public-private action was more successful in achieving a stable regional timber economy than was federal action alone. As another example, to serve the demands for outdoor recreation in New England, it may be more effective to improve state and local parks near the population centers than to develop more capacity on the White and Green Mountain National Forests. Yet national forest management planning explicitly excludes consideration of such alternatives.

The State and Private Forestry (S&PF) branch of the USDA Forest Service has suffered hard times recently. A conservative administration abandoned S&PF's historical mission of subsidizing timber production on private lands. An alternative, useful role would seek out those occasions where the best solutions to national forest problems lie on private or nonfederal public lands.

Implementation

Plan implementation carries many difficulties. Beuter and Iverson note the unrealistic budgets coming out of the current round of forest planning. Plans are implemented through budgets. What is the use of planning for a budget which is unlikely to be funded? At least some analytical effort should be devoted to exploring alternatives where the budget is constrained to realistic levels. This problem also occurs in the national RPA plans.

Optimal forest plans do not simply "scale down" in response to budget constraints. That is, the optimal mix of program elements will shift as increasingly strict budget constraints are imposed. At a high budget level, the optimal plan might call for much recreation. As the budget is lowered, the optimal program mix might well be skewed towards a larger emphasis on timber.

The gulf between assumed and actual budgets is not the only impediment to implementation. Other model assumptions may be at variance with reality. For example, the marginal willingness to pay for recreation on national forests is, by definition zero unless a user fee is levied. In a linear programming framework, a positive value for recreation must be used to insure that, on average, the land allocations are correct. But any prescriptions which call for additional recreation investment will be correct only if a fee equal to the assumed marginal willingness to pay is actually levied. Otherwise, what guarantees that the recreationists who value the new facility are the ones who use it? The same problem would arise if a FORPLAN simulation valued timber at $150/mbf; but management practice gave timber away at no cost.

Benefits

So, the costs of NFMA planning in general and FORPLAN in particular seem large. What are the benefits? Beuter and Iverson point out that the theoretical objective of FORPLAN is economic efficiency: to maximize net present benefits subject to constraints describing forest production possibilities, environmental regulations, and legal requirements. Haigh and Krutilla(1980) go further to describe economic efficiency as a requirement of the National Forest Management Act. Does FORPLAN achieve this objective?

Partially. FORPLAN is apparently effective in eliminating prescriptions which are not cost-effective. This is no small task. But the larger objective of overall economic efficiency is not always served. Even where economic optimization is given free rein in FORPLAN, the resulting plan is unlikely to be selected as the preferred alternative. Others in this symposium have stressed the utility of FORPLAN as a simulation tool. If simulation is the objective, then linear programming is a poor analytical approach, and the principal benefit of linear programming--identification of economically efficient plans--is lost.

While economic efficiency might underlie NFMA, reconciliation of political discord was an overriding objective of the new planning procedures. The Giltmeir Index--the number of lawsuits filed against the Forest Service on matters of policy and management--is a useful measure of how well the Forest Service has achieved this objective. The definitive statistics have not been compiled, but Giltmeir (personal communication) reports that the Index is probably down as administrative appeals have supplanted formal legal challenges. Perhaps the Giltmeir Index will rebound as these appeals mature into court cases, or perhaps it will remain quiescent as controversies are reconciled through administrative channels.

The long-term success of NFMA planning in reconciling discordant visions of the national forests remains unproved. Earlier in this symposium, two Forest Supervisors--Orville Daniels and Steve Mealy--gave optimistic views. Because FORPLAN is essentially a nonincremental, "zero-based" planning model, all the tough decisions surface at once. As a consequence, political discord peaks during the period when the plans are being prepared. Optimistic views of the planning process presume that the decisions forged during this contentious period will hold together throughout the planning cycle, and thereby the discord will be reduced over the longer run. Is this optimistic view warranted? The next decade's performance of the Giltmeir Index will provide part of the answer.

If Not FORPLAN, What?

Some trace the origins of cost-benefit analysis to Benjamin Franklin. Faced with a decision, he is supposed to have listed the costs in one column and the benefits in another, and decided according to the relative lengths of the two columns. Using this criterion, I am reluctantly skeptical about the net benefits of FORPLAN.

This begs Beuter and Iverson's final question: "If not FORPLAN, what?" They argue that FORPLAN, or something very much like it, will occupy a central place in forest planning for quite some time. I agree. Sunk costs, so capriciously dismissed by economists, weigh heavy on administrators. Long bureaucratic memories and sheer institutional momentum guarantee happy pasture for formal planning models such as FORPLAN. A relevant question is how to improve the utility and performance of FORPLAN. Here, I have two suggestions.

First, because FORPLAN is a market-like model, make greater use of market-like incentives. In the management of the national forests, for example, levy fees for recreation and wilderness use (Binkley and Mendelsohn 1987 discuss the advantages of using fees in outdoor recreation management). Imposing recreation user fees would bring management reality into concert with the economic assumptions behind the forest plans. Imposing fees would generate believable estimates of the value of recreation. Most important, imposing fees could create new revenues for the Forest Service. These revenues could fund the many, high economic return recreation investments which apparently exist on the national forests (Binkley and Hagenstein 1986).

Similarly, use market-like incentives in the forest management organization. In a 1981 Resources for the Future conference on management of the national forests, I proposed that each national forest be organized as a profit center in the accounting sense (Binkley 1983). Where they exist, use market prices to value the inputs and outputs associated with management of the forest; where market prices do not exist, impute surrogate prices. Pay the forest supervisor, district rangers and others of the forest according to the annual net surplus. To do so would require a set of accounts which would separate legitimate capital investments from operating expenses. By themselves, these accounts would help in analyzing some of the current national forest management controversies such as the so-called below-cost timber sales problem. If economic efficiency is an objective of using FORPLAN in NFMA planning, then market-like incentives in management and organization would surely help achieve it.

Second, do needed research on land management planning. The usual research and development processes were not followed in developing FORPLAN. There apparently was little peer review, and no peer-reviewed publication of the model as it was developed. Those outside the immediate circle of developers had little access even to the grey literature on the model. Lack of participation by the wider research community, particularly the research division of the USDA Forest Service, is surprising. Three areas seem to warrant particular attention in future research on land management planning:

i. Analysis of the analytical process itself. What were the costs and benefits of the first round of planning? How did actions change in response to land management planning?

ii. Institutional factors. How did the Forest Service change in response to FORPLAN? What kinds of information were systematically ignored because of the modeling efforts? How can this information be brought back into the planning process? What are the limits of procedural rationality in national forest planning? How much technical information can be transmitted via the political system?

iii. Large-scale modeling systems. Beuter and Iverson usefully distinguish model efficacy from model efficiency, pointing out that the first implementation of any system is not likely to be very efficient. But now it is time to turn to questions of efficiency. Can the recent advances in solution algorithms for linear programs--Karmarkar's algorithm, gradient projection techniques,...--be usefully exploited in the kinds of problems which arise in land management planning? Are there fast heuristics to take advantage of any special model structures typical of FORPLAN problems?

Formal, quantitative modeling has a role in planning, managing, and developing policy on the national forests. Much work remains to exploit the full power of formal analysis. Given the size and importance of land management planning, research on the technical and institutional aspects of the problem should be expanded.

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An Ecological Evaluation of FORPLAN in National Forest Planning

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Abstract.--This paper evaluates the software package used to formulate linear programming models for use in forest planning (FORPLAN) from an ecological perspective. The evaluation centers on three major topics: (1) philosophical criticisms of the FORPLAN approach, (2) technical considerations when modeling ecological systems using FORPLAN, and (3) improving the ecological content of the FORPLAN system.

The FORPLAN system (Johnson 1986, Johnson et al. 1986) is a very large (and complex) algorithm. The FORPLAN versions 1 and 2 and their antecedents represent an attempt to quantitatively deal with the myriad of problems that arise from attempts to maintain forests as productive ecosystems for multiple-valued goals (money, recreation, wildlife, endangered species preservation, etc.) over a long period of time. To say that the management problems that attend such an assignment are difficult is to understate the problem. The entire development of the quantitative approach to this problem is itself the topic of interesting historical accounts (Jones 1986, Iverson 1986). The approach that will be taken in this paper will be to evaluate the FORPLAN System's ability to model ecological systems from the point of view of an ecologist outside the Forest Service. Three topics will be treated in this discussion:

1. Philosophical criticisms of the FORPLAN approach.
2. Technical considerations when modeling ecological systems using FORPLAN.
3. Improving the ecological content of the FORPLAN system.

Several (if not all) of the points that will be raised undoubtedly have been considered and put aside for one reason or another by people in the Forest Service and probably by the very able team that has developed the FORPLAN code. Whenever possible, examples from the field of ecological modeling will be used in the discussion of these various points. FORPLAN might be viewed as a lump of clay, available to be molded into many different shapes based upon the desires of the sculptor. It could be used to model aspects of ecology yet undreamed of by users. However, this paper will focus on the use of FORPLAN as an analysis tool in the existing forest planning process (Forest Service Manual Chapter 1900). We will not try to compare FORPLAN against alternative analysis tools that may have been or may be used in the future. Nor will we speculate on hypothetical planning processes which may have used FORPLAN in a context other than as a land allocation and activity scheduling tool. Rather its adequacy as an ecological analysis tool will be evaluated.

PHILOSOPHICAL CONSIDERATIONS IN USING LARGE MODELS

In reading the comments on the vices and virtues of the FORPLAN model (Bailey 1986), clearly, some of the arguments arise from what are differences in points of view. This is not to trivialize these arguments because often these differences have their bases in philosophical views about modeling processes. Also, many of these positions are not unique to FORPLAN but have been a part of discussions about other ecological modeling efforts.

DISTRUST ARISING FROM MODEL COMPLEXITY

Large models generate distrust among some members of almost any scientific community. For these scientists, large models seem to be a contradiction to the "Ockham's razor" principle of parsimony that is the basis for much of western science. Even without a more parsimonious explanation, many scientists are likely to be suspicious of the scientific rigor of any very complex explanation.

The general distrust of large models is in no way unique to the FORPLAN model. For example, the International Biological Program was regularly bombasted on the basis that the computer models that it was developing were overly complex and thus non-scientific (Watt 1975). It is fair to say that a segment of the scientific public will simply not be attracted to large models and that their position is historically quite defensible in terms of the development of modern science. The position on this issue taken by so many of our peers sets a strong priority on demonstrations of the effectiveness of large complex models over other approaches. It is harder (in the sense of model validation) to push a complex model to a given level of scientific acceptance than it is for simpler, more theoretical, models.

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A point that is related directly to the size of models and to pragmatic considerations involves the propagation of errors in model parameters and the reliability of the data in large sets of input data. The experience in most ecological modeling exercises has been that models of intermediate complexity have normally had the greatest forecasting ability (O'Neill 1975). This can be attributed, in part, to the fact that almost all parameters in ecological models have error in their estimates. It is a nontrivial problem to identify whether it is a worse error to leave out a given feature in a model rather than include it when there is error in estimating the parameters associated with its incorporation in the model. In most ecological models, this problem cannot be solved by a rule of thumb. Most sensitivity analyses of large models focus on a few parameters that appear to be the dominant factors for a given model application. One might presume (as has been done regularly) that if the error in the more sensitive model parameters is under control then the model predictions will be reliable. In cases in which the model is being used to interpolate system dynamics this may well be true, but the potentially dramatic impact of model structure on sensitivity analysis must be kept in mind.

DIFFICULTY IN COMPARING INTUITION AND MODEL RESULTS

Somewhat related to the sorts of considerations just mentioned concerning large models is the difficulty in being able to develop an intuitive understanding about why a model produces a given result. This criticism places the model developer in a rather difficult position in that large models are often developed specifically to investigate problems for which there is no intuitive solution. Even if this criticism attacks the model for doing exactly what it was designed to do sometimes,a real problem is that users distrust models that produce answers which are hard to infer from the causes. The solution of the problem probably lies in exercising the model to the extent that the user is more familiar with the inner workings of the algorithms, but this approach involves the user learning a lot about the model but not necessarily a lot about reality (Barber 1986).

COMPUTER COSTS INVOLVED IN RUNNING MODELS

Large models are often expensive to run on computers or at least appear expensive to the non-computer aficionado. This is the case with implementations of the FORPLAN model on more complicated problems. The cost of computer time is something of a red herring in that the cost of conducting research under field conditions (at least in the ecological sciences) is usually larger than these computer costs by a great margin. This is the case even when the data collection is justified by a model development goal. The criticisms relating to model complexity just discussed have as their solution more frequent implementation of the models on computers. If one would like to do sensitivity tests, to determine the effects of data error structures on model performance, or even allow a model user to become more familiar with the model behavior, it follows that there will be more computer time spent on the models to accomplish these goals.

TECHNICAL CONSIDERATIONS WHEN MODELING ECOLOGICAL SYSTEMS USING FORPLAN

THE ECOLOGICAL IMPLICATIONS OF THE NATIONAL FOREST MANAGEMENT ACT

Before one can evaluate any model there must be a basis upon which to judge the value of the tool. In this instance, it seems most fair to judge the FORPLAN model against Section 6 of the National Forest Management Act (NFMA). One might argue that the regulations also provide a basis for judgment, but they are one step removed from the act itself and embody extensive interpretation. Also, the regulations may have been written with a particular tool in mind, thereby imparting some bias in their requirements. Therefore, we will use the act alone as the anchor for the evaluation.

The principal points made in Section 6 of the National Forest Management Act concerning ecology can be summarized succinctly. NFMA Sec. 6 (e)

"(1) provide for multiple use and sustained yield of the products and services obtained therefrom in accordance with the Multiple-Use Sustained-Yield Act of 1960, and, in particular, include coordination of outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness; and

"(2) determine forest management systems, harvesting levels, and procedures in the light of all of the uses set forth in subsection (c)(1), the definition of the terms 'multiple use' and 'sustained yield' as provided in the Multiple-Use Sustained-Yield Act of 1960, and the availability of lands and their suitability for resource management.

NFMA Sec. 6 (g)(3)

"(A) insure consideration of the economic and environmental aspects of various systems of renewable resource management, including the related systems of silviculture and protection of forest resources, to provide for outdoor recreation (including wilderness), range, timber, watershed, wildlife, and fish;

"(B) provide for diversity of plant and animal communities based on the suitability and capability of the specific land area to meet multiple-use objectives, and within the multiple-use objectives of a land management plan adopted pursuant to this section, provide, where appropriate, to the degree practicable, for steps to be taken to preserve the diversity of tree

species similar to that existing in the region controlled by the plan.

Another major feature can be summarized as a concern for environmental protection. This can be seen in the inclusion of requirements for reforestation, limitations on suitable acres for timber harvest, and an admonition to identify and recognize potential hazards. It is interesting to note that economics is only briefly mentioned in Section 6 of the NFMA (Sec. 6 (g)(3)(A)).

ANALYTICAL IMPLICATIONS OF THE NATIONAL FOREST MANAGEMENT ACT

What then are the analytical implications of these ecologically related points? The references to the Multiple-Use Sustained Yield Act simply lay a foundation upon which to build improved forest management. From an analytic standpoint the major implication is that one must be able to consider sustained yield of all multiple-use products and services.

The Forest Service is also directed to coordinate all resource management. On the surface this may not seem to be more than an elaboration of the multiple-use concept. However, upon further investigation of the meaning of "coordination" as used in the Act, one finds that there are significant ecological implications. Coordination implies to make of the same order or importance. In terms of resource management and as used in the act, "coordination" implies that no resource may be emphasized to the degree that minimum requirements for any other resource are violated (Salwasser and Mealey 1983). This direction from Congress has significant implications for forest planning analysis. Specifically, it implies that what has come to be called minimum management requirements must be portrayed in the analysis.

Section 6 (e) (2) requires some method be used to choose among alternative management systems based on their economic and environmental effects. Considering economic and environmental effects of management systems implies the ability to show not only simple effects, but the interactions among the managed resources. To understand the resource interactions is to understand the ecological processes upon which they are based. The challenge is to be able to estimate the ecological effects of resource management at the geographic scale of a national forest.

Perhaps the most explicitly ecological requirement of the act is in the phrase "provide for diversity of plant and animal communities..." Section 6 (g)(3)(B). Although the interpretation of the term diversity is problematic, an operational definition has evolved and has been incorporated in the NFMA planning regulations: "the distribution and abundance of different plant and animal communities and species within the area (a National Forest) covered by a land and resource management plan." (36 CFR 219.3). The important implication for the analysis is that this requires that both the distribution and abundance of plant and animal species be considered. No requirement to model this information was specified, but one can well imagine that satisfying this requirement has caused the Forest Service considerable head scratching.

Probably one of the key concepts to be found in the NFMA is the notion of integrated management, trying to capitalize on symbiotic relations that exist in nature through management. This in turn makes the examination of ecological interrelationships a critical part of the forest planning analysis. When one adds to this the environmental and productivity protection language woven through the act, apparently both the positive and negative effects of management choices must be considered. These positive and negative effects run the gamut from simple relationships, such as the quantity of wood fiber harvested, to complex cases of determining the effects on the viability of a wildlife population. Such diverse requirements pose problems for any single analysis tool. These problems are compounded when such diverse relationships must also be portrayed over an area the size of a national forest, most of which are over a million acres in size. Fortunately, there is no requirement in the NFMA to use any particular analysis tool, nor is there a limitation on the number of tools that can be used. However, given all the analytic requirements in forest planning, there is an intuitive appeal in minimizing the number of analytic steps required.

A couple of additional points need to be made about the analytical implications of the NFMA before further developing the ecological evaluation of FORPLAN. First, both protection and dealing with hazards can be viewed proactively and reactively in forest planning. The proactive view holds that management activity can help protect and enhance the productive capacity of the land. Similarly, many potential hazards can be avoided or reduced through knowledgeable management. The reactive view is to handle protection through constraints on management activities, both in terms of mitigation and preservation to protect and avoid hazards. Both views have their place in forest planning analysis, and the analysis tool used should accommodate both approaches. Second, the requirement to provide for diversity of animal and plant communities is a major ecological requirement. Diversity was chosen as a proxy for many ecological considerations. When the act was written it was commonly held among ecologists that increased diversity in ecosystems led to increased stability. Including diversity in the act was also a way to combat extensive vegetation-type conversion, which was a motive in the creation of the NFMA. Since that time, the science of ecology has progressed and more factors than diversity have been identified as contributing to stability.

THE BASIS FOR THE EVALUATION

In evaluating FORPLAN, it is important to understand that there are three possible dimensions to the discussion. The first dimension relates to the fact that a linear programming algorithm is used to solve the models created by the FORPLAN matrix generator. The second dimension pertains to the actual models created on a particular National Forest using FORPLAN. The third dimension is FORPLAN itself, the matrix generator and report writer, which are used to create the models which are, in turn,

solved using linear programming. There are interactions among the three dimensions. However, every effort will be made during the evaluation to keep the distinction clear about which dimension of FORPLAN is being discussed.

The approach that will be used to evaluate FORPLAN will be to examine facets of ecology which must be addressed if the intent of the National Forest Management Act is to be met. The ecological facets which will be examined are:

1. Non-linearities in Ecological Relationships.
2. Variations in Ecological Time Scales.
3. Multiple Resource Interactions.
4. The Spatial Dimension of Ecological Relationships.
5. Variation and Error in Model Coefficients.
6. Uncertainty in Ecological Processes.
7. Succession and Mortality.
8. Dynamic vs. Static Representations of Ecological Processes.
9. Vegetative Structure.
10. Delineation of Land Units for Analysis.

The facets that have been chosen for examination are the most significant and challenging in terms of successfully modeling forest dynamics. Where appropriate, we will discuss how FORPLAN deals with each facet and the problems that arise. Also, approaches used to solve or circumvent the problems will be addressed. During the evaluation it will be noted where problems stem from the assumptions of linear programming as opposed to problems created by the FORPLAN matrix generator and report writer.

Non-linearities in Ecological Relationships.

The use of linear programing as the algorithm in the FORPLAN model has attendant assumptions about the linearity of the problem. Linear programming has its best applications in problems in which the optimal solution locally is also the globally optimal solution or in which one is interested in making small changes in a management strategy that is already near a local optimum. Problems with regards to these and other linearity assumptions lead to the use of nonlinear optimization procedures.

There is considerable debate in ecological sciences about the linearity, or lack thereof, in ecosystems. In a practical sense, many non-linear relationships can be adequately represented by linear approximations, particularly non-linear functions of time. Even here, non-linear responses from management activities that alter internal system dynamics can be very difficult to represent. An example is road building. A watershed may tolerate road building up to a point beyond which catastrophic erosion may take place (an internal change). This sort of relationship is difficult to portray in a linear programming model because it violates one of the implications of the linearity assumption; that of proportionality. Another example of this sort of difficulty is attempting to model wildlife habitat capability. Efforts have been made to incorporate a habitat capability model which is a non-linear function of the age class distribution of the vegetation into a FORPLAN model (Holthausen 1985). It is possible to track the age class distribution of stands in the model, but it is not possible to dynamically calculate the habitat capability index, even if it could be linearized, during the model execution. For Holthausen (1985), the habitat capability index was calculated outside the model execution and therefore biologists were unable to use it as an objective function in the model.

An alternative approach is available to allow habitat indices to be incorporated into the model. This involves delineating a geographic area in FORPLAN, specifying the anticipated age-class distribution of the vegetation and calculating the habitat capability index as it changes through time outside of FORPLAN, and then entering the resulting yield stream into FORPLAN. This would represent one possible choice for the area in question and the same procedure could be repeated for other choices. A similar approach could be used for the road example.

Variations in Ecological Time Scales.

Some ecological processes have rapid dynamics. For example, certain pest outbreaks may run through a complete cycle in less than 10 years. Some wildlife species complete an entire life cycle in a year. Trees, however, typically require over a century to reach maturity. Different time scales for the dynamics of system elements make model development difficult and, therefore, have plagued modelers. The problem is often resolved by selecting a timeframe of interest and then attempting to include those processes with the ability to respond dynamically in the timeframe in the model. Another approach is to represent different model components at different time scales. This approach has the potential to add complexity to an already complex analysis and is not often used by forest analysts.

In developing forest management plans, it is agreed that the analytic investment should be placed on the near term where there is the most payoff. This argues for smaller time steps in the short term and longer time steps in the long term. However, this is not as easy as it seems given the requirements of the NFMA on how the timber analysis must be conducted. FORPLAN model size can be attributed in part to these requirements. Nevertheless, FORPLAN has capabilities to reduce the number of constraints in the models by allowing time periods late in the planning horizon to be combined into intervals.

Multiple Resource Interactions.

Linear programming techniques function to optimize a problem concerning a single commodity (an economic criterion such as present net value (PNV) is commonly used in FORPLAN models) subject to some constraints. Attempts to include the economic value of nonmarket

resources is not always well received because of the difficulties in establishing mutually agreeable willingness to pay estimates. Furthermore, the focus on economic objective functions undoubtedly raises the ire of environmentally oriented users of the model in that it tends to put certain values (recreation, wildlife, water quality) in the defensive position of constraining the economic productivity of the nation's forests.

The situation is more than simply a semantic matter arising from "constraint" being a somewhat pejorative term (particularly when one is constrained from making money). The objective of Forest Service management strategies is to optimize multiple-use of the nation's forests. It is not at all clear that the management strategy for optimizing money developed by using the FORPLAN model under a constraint of maintaining a given level of animal species diversity would even resemble the optimal strategy for optimizing diversity under the constraint of producing a certain cash flow. If the choice of the single commodity used in the model influences the development of the multiple-use optimal strategy, it may well be appropriate to investigate the sensitivity of model output to this feature. An approach to accomplishing this is provided by Dress (1982). Although Dress advocates using a goal programming formulation to generate alternatives, this does not appear to be a requirement for the general approach. Forest Service policy requires a benchmark analysis which is very similar to the methodology outlined by Dress. Separate FORPLAN models are run with an objective function representing each of the significant resources on a forest. The results from the runs establish a decision space within which all alternatives must lie. The only problem with this approach is that it is difficult to insure no inferior alternatives (solutions where one or more of the resources could be improved with no cost to the others) are used in decision making because of the number of dimensions in the decision space.

Spatial Relationships.

Spatial relationships are critical to the understanding of ecological processes and, therefore, to their management. The juxtaposition of wildlife forage, hiding cover, thermal cover and birthing areas are critical to the viability and productivity of local populations. Similarly, contagion factors are critical in determining the extent and severity of many insects and disease. Because entering such detail in Version 1 of FORPLAN often led to enormous models, early FORPLAN models often lacked much spatial content. Instead, early models had homogeneous analysis areas scattered across the National Forest with per acre coefficients (Strata-based approach) (Johnson et al. 1986). Enhancements available in Version 2 make it possible to enter both the costs of management specific to an area, such as road costs, and the effects of management on an area; especially ecological effects such as vulnerability to a pest outbreak and sediment production including the consequential effects on aquatic wildlife. This capability is provided by a second level of stratification imposed upon the more traditional homogeneous analysis areas (Mixed strata-based, area-based approach (fig. 1) (Johnson et al. 1986). Although this is a major step forward, it comes at the expense of increased model complexity (there are now two levels of stratification and two types of prescriptions) and not all spatial problems are solved. For example, if site specific detail on the timber harvest schedules are desired then model size can still be a problem.

Difficulties in representing the spatial facet are primarily attributable to the size of National Forests which are being modeled. Both FORPLAN and linear programming have the ability to model rather intricate spatial relationships (See the paper by Ryberg and Gilbert (1986) for an example of using FORPLAN to represent spatial relationships). However, some uneasy compromises have been forged in attempts to incorporate spatial content into forest-wide models.

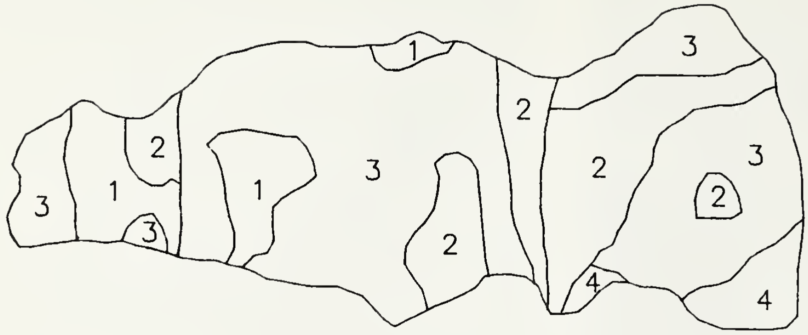
Variation and Error in Model Coefficients.

A significant question in the development of ecological models is how to deal with great variability and error in coefficient estimates. Not only do individual populations of flora and fauna generally posses wide ranges of variability, but there is also a wide range of variability between different populations. For example, some timber stands may be very homogeneous, and if you compared stands of the same species on similar sites they would have similar variability (Moeur 1983). But, wildlife living in the same stands could vary dramatically in number because of some small-scale habitat requirements such as snags, fallen decaying trees, and berry producing understory shrubs (Shugart and Urban 1986). The question then becomes, should coefficients with such different variability be included in the same model and if they are, what are the effects on the solution, both in terms of resource outputs and land allocations? A similar question can be raised about error in coefficients.

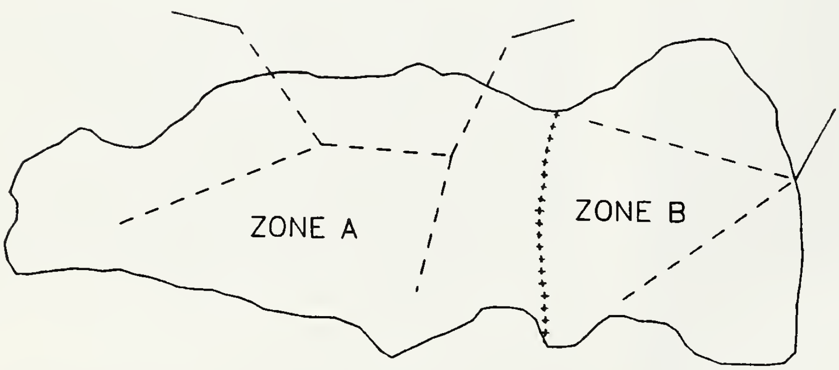
Methods for circumventing this problem are to improve data, refine the land stratification to reduce variability, and leave variables with high variability or error outside of the model. Those variables left outside the model must then be incorporated into the alternative evaluation and selection process by other means.

Uncertainty in Ecological Processes.

One of the major difficulties in modeling ecological systems is providing realistic representations of uncertain events. Unpredictable diseases can affect both animal populations and their habitats. Natural disasters, such as floods, fires, and volcanoes can cause major changes in the environmental structure. Ecological studies have helped managers understand that some "disasters," such as fire, may have the beneficial effect of rejuvenating successional communities. No matter what analysis procedure is used, the real burden of dealing with uncertainties falls on the decision maker who must determine how much risk he or she is willing to accept.



Strata	Definition
1	Loblolly pine seedlings and saplings
2	Mixed hardwood poles
3	Loblolly pine mature
4	Meadow



Analysis Area	Age	Acres Zone A	Acres Zone B
1	5	200	0
2	15	150	150
3	35	450	250
4			100

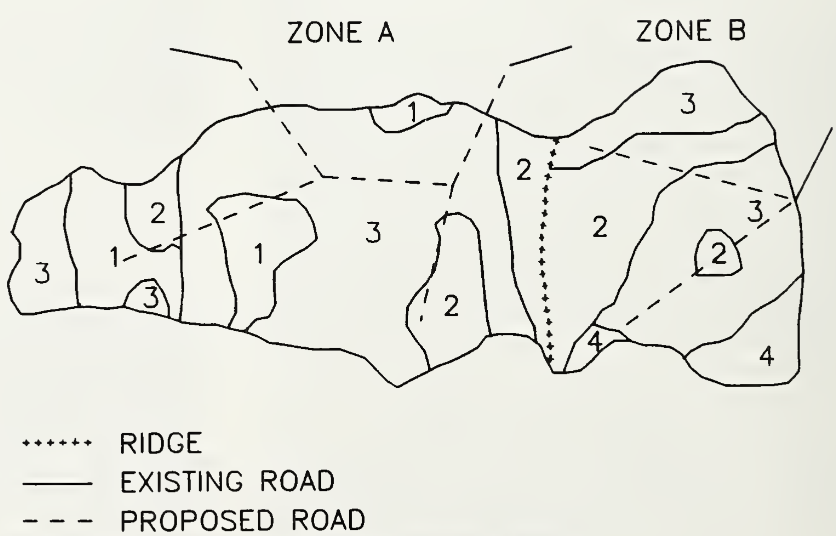


Figure 1.--Maps which illustrate the concept of a dual stratification called a mixed strata-based, area-based approach (Johnson et al. 1986).

Models differ in their abilities to unravel the uncertainties embodied in ecological processes. Three different schools of modeling: optimization, simulation and control theory, all have methods for handling uncertainty (Bare and Schreuder 1976, Walters and Hilborn 1978). Usually, the analysis becomes more complex and less feasible for large problems. As a result, one must weigh the benefits of including uncertainties against the costs of increased complexity. One noteworthy example of considering risk with FORPLAN is the application to the problem of population viability used by Salwasser et al. (1984). Salwasser et al. (1984) estimated the habitat requirements necessary to sustain a viable population of a wildlife species at a prescribed risk level outside of FORPLAN. Then constraints were added to a FORPLAN model to insure the required habitat was part of the solution for each alternative. Higher levels of habitat could also be an objective in wildlife or amenity alternatives.

Another tack is to acknowledge that the coefficients in the LP represent the potential for resource production. An example, is the use of harvest dispersion constraints. Typically, these constraints are imposed over a large area and limit the rate of harvest to a level which provides the potential to lay out cutting units without creating openings which exceed the minimum management requirements. It is then left to the people who carry out the plan to determine whether the desired results can be achieved.

The dilemma is deciding how much detail should be carried in the forest planning analysis tool and how much should be handled in separate steps. On the one hand, as more capability has been added to FORPLAN, it has become more complex to understand and use. However, if pieces of the analysis are handled outside of FORPLAN, then one must learn an additional system and deal with suboptimality issues. Perhaps a happy medium can be found to resolve this dilemma.

Succession and Mortality.

Succession plays a vital role both in modeling growth processes and in the classification of lands for the stratification process. Vegetative treatments and natural processes (fire and other disturbances) have the potential to reset succession with important management consequences. Successional stages at the beginning of the planning horizon are well portrayed in most FORPLAN models. Most FORPLAN model users develop age dependent relationships to help track characteristics of the vegetation deemed important from an ecological and management standpoint. It would be very helpful if the FORPLAN model had more inherent capability to track different successional stages. This would likely result in more consistency among National Forests and would also relieve some of the modeling burden from the analysts. However, this would be difficult to standardize in a general purpose tool such as FORPLAN which is used across all National Forests.

The importance of succession and mortality has been recognized by the developers of FORPLAN. An approach for dealing with this important ecological process has been developed (Johnson and Stuart 1984) and will be incorporated into Version 2 next year. The approach taken is a generalization of the Model 2 structure that has always been a major component of Version 1 of FORPLAN (Johnson and Crim 1986). It will provide inherent capability to examine such forest dynamics as differential regeneration success, stand mortality and a general decision tree approach. This capability will extend the Model 2 structure and should greatly enhance FORPLAN's ability to more realistically represent forest dynamics including probabilistic outcomes. However, these options will have to be used judiciously, otherwise model size and coefficient density could be a problem (Johnson and Stuart 1984).

Dynamic Versus Static Representations of Ecological Processes.

A major concern when using a static model such as linear programming is the inability of the method to represent dynamic ecological processes. Many authors have suggested alternative ways to approach forest dynamics such as simulation and dynamic programming (Bare and Schreuder 1976, Jameson and Bartlett 1986). The well known problem of dynamic programming being unable to handle very many variables prevents it from being a serious contender. However, simulation models have proven to be capable of representing forest dynamics (Boyce 1978, Shugart 1984, Stage et. al 1986). The approach often used in forest planning is to use simulation to predict the ecological dynamics, and then to use the predicted yield streams as components of the decision variables in FORPLAN models. Another aspect to consider is that many dynamic programming problems which meet the proper assumptions can be represented in an equivalent linear programming formulation. However, the number of linear programming columns may be prohibitively large. The point is the simulation/linear-programming approach described above can be thought of as an attempt to create a sample representation of the true dynamic problem. One also must question the effort that should be applied to dynamics that are hypothesized for distant time periods.

The static assumption of linear programming gives the appearance that it is an open loop system (Casti et al. 1983, Jameson and Bartlett 1986). However, FORPLAN models will be updated, at a minimum, each planning cycle and solved anew, thereby incorporating some level of feedback. Solutions from existing FORPLAN models will not necessarily be followed for 50 to 150 years, rather they will be modified and improved as new information is developed.

Vegetative Structure.

A characteristic of all vegetative communities, that is particularly evident in forests, is vertical layering of the canopy and understory structure. There is great variation in the importance of the understory or overstory in different forest types. In many instances, however, the different canopy layers can have important consequences in terms of

forest production and wildlife habitat. Although both Version 1 and 2 make provisions for handling two storied stands, Version 1's capability is oriented toward timber. In Version 2, the age of two storied stands created in the model will be tracked and hence wildlife and other relationships can be represented if they can be defined in terms of either overstory or understory age. Multiple storied stands could also be represented using the multiproduct capability of Version 2 but again this would add to the complexity and cost of the model, not to mention the way it would test the user's creativity and gumption. The vertical layering in forest canopies is challenging to model satisfactorily using FORPLAN. Whether this kind of detail is critical to the forest planning analysis depends on the questions being addressed.

Delineation of Land Units for Analysis.

One of the fundamental building blocks of any ecological model is the definition of units of land to be used in the analysis. In FORPLAN the units of land for which management choices (prescriptions) are considered in the linear programming algorithm are called analysis areas. Analysis areas are a requirement in FORPLAN models and every National Forest has defined them. Land is delineated or stratified into units based on the interaction of several ecological components, such as soils, relief, climate, and vegetation. The implicit assumption is that the derived units reflect differences in potential response to management and resource productivity. Surprisingly, there is large variation in the way the analysis areas have been defined from forest to forest. One argument for this is that the planning problems being addressed change from forest to forest. Definition of land units also relates to the spatial content of the analysis and ecosystem under consideration. Therefore, changes in the importance and nature of spatial arrangements from forest to forest can result in different approaches to land stratification. The definition of analysis areas is important in that the yield coefficients for representing production and other interrelationships are developed based upon the assumptions of the underlying units of land (Bailey 1984). This is the first point where incipient variation and error can be introduced into the model by land delineation decisions that are made. It also has a strong bearing on the adequacy of the model for representing ecological processes. For example, if analysis areas are homogeneous units scattered over the entire forest, it may provide for accurate timber volume estimates, but it would be impossible to accurately portray habitat capability for wildlife species that need different kinds of stands within their seasonal home ranges for feeding and cover.

Although some models have been constructed which sacrificed precise homogeneity to increase the spatial content of the analysis areas (which often results in fewer analysis areas), the models have been criticized for being unable to prove that consideration was given to a sufficient range of timber harvest timing choices (management regimes). It would be helpful if the minimum set of timber timing choices that would be necessary to provide a "wide range" could be identified outside of the forest-wide model and be subsequently built into a set of prescriptions which could be applied to larger spatially oriented analysis areas. (See Mitchell (1986) for an approach for selecting relevant timber management regimes).

SUMMARY OF THE ECOLOGICAL EVALUATION

The foregoing discussion emphasizes the fact that ecological modeling for multiple-use in forest planning is much more complex than the single stand analyses that are reported in much of the scientific literature. It involves representing not only multiple stands, but also multiple ecosystems. One might argue that the Forest Service should not be trying to do such comprehensive planning forest-wide, and yet the National Forest Management Act states that a single plan must be produced.

Attempting to represent all the complexity of ecological systems can be overwhelming on the scale of forest planning. The forest planning analysis tool must be able to handle not only ecological, but economic and production aspects of a forest as well. It must not only be able to represent forest dynamics, but also help allocate lands for multiple-use goals. It is, therefore, a meeting place for the results of preprocessors for such things as timber volume tables, demand estimates for developed recreation and the habitat requirements to sustain viable populations of indicator species. On the output side of the analysis, vegetation structure, rates of harvest, estimated road construction, etc. can be used to drive models which simulate the effects on ecological processes which are too complex to include in the FORPLAN model. However, this approach is less satisfying than running more detailed models before the forest-wide analysis and then using their outputs as proxies for the detailed interactions. Any model chosen must be capable of filling this role and handling large implementations.

IMPROVING THE ECOLOGICAL CONTENT OF THE FORPLAN SYSTEM

The National Forest Management Act has put an interesting and demanding challenge to the planner and the ecologist. The most fruitful approach for injecting additional or increased ecological richness into the FORPLAN Version 2 system would appear to be in the pre-processing of input into the model along with post-processing of solutions produced by the model. Adding this level of detail to the FORPLAN matrix generator and report writer would probably make FORPLAN overly complex. Furthermore, ecological sciences do not have a tradition of using linear programming to any great degree when compared with the well-developed traditions of statistical applications and differential equation models. Therefore, we will examine how some of these approaches could be used to improve the results obtained from FORPLAN.

It will be important to keep in mind a critical distinction between two analytical needs during the following

discussion. First, there is a need to provide analytical tools which help resource managers understand and predict ecological responses in managed and unmanaged conditions. An array of ecological tools are available to meet this need and they will be discussed below. Generally, these tools are classified as simulation models. The tools in this class are typically not used to simulate an entire forest at once. Second, there is a need to help managers choose the best management alternative to achieve multiple-use objectives based in part on ecological effects. Simulation models can be instrumental in predicting ecological effects at a sophisticated level; however, the second need cannot be met at the forest-wide level if too much detail is carried into the analysis and decision making process. But, the results from simulation models can be abstracted and macro parameters or relationships can be used in an optimization model to help select the "best" alternative. Figure 2 illustrates the concept of using simulators with forest data to provide input into FORPLAN.

The objective is to provide information which allows the exploration of resource production potentials using ecologically sound management. Attempts have been made to accomplish these objectives by creating decision variables for the LP model which are designed for independent, homogeneous analysis areas and using constraints to achieve spatial feasibility. An alternative approach can also be used when one realizes that activities in a geographic area are not independent either in terms of the activities themselves or the consequences of the activities. Decision variables developed based on this philosophy include an implicit land allocation objective and a resource activity schedule besides the environmental effects. The activity schedule is designed spatially and temporally to meet the management objectives implied by the prescription and to comply with the attendant standards and guidelines for such things as maximum opening size and wildlife habitat dispersion requirements. This general approach, whether it is purely area based or a mixed area based, strata based approach will be termed coordinated scheduling to simplify the remainder of the discussion (Iverson and Alston 1986).

Several ecological research areas seem to lend themselves to consideration in this regard. In this final section we will discuss some possible considerations that could improve the FORPLAN Version 2 system in its capability as an ecosystem analysis tool used for the maintenance of the diversity of species (which we earlier identified as one of the principal ecological foci in the National Forest Management Act). The approach proposed also can be generalized to include other resources such as water, range and timber.

HABITAT MANAGEMENT: CONCEPT DEVELOPMENT AND EXAMPLE CASES FROM THE USDA FOREST SERVICE

Continued presence of suitable habitat for the species over time is an ecological analog to the problem of managing a forest for a sustained yield of forest products. Habitat is defined as the kind of place(s) where individuals of a plant or animal species can survive, grow and reproduce. A species' habitat is often quantified in terms of the ranges of physical and biotic factors associated with the presence of individuals of the species. For many animals and particularly for vertebrates (Morse 1968, Shugart and Patten 1971, Dueser and Shugart 1979, Franzreb 1983) the structure of the vegetation is a major element in determining the suitability of the habitat (Hilden 1965). Because the vegetation can be altered by both natural (succession, disturbances) and human-controlled processes (timber harvest), the ability to project vegetation change over time is an essential element both of managing certain species' habitat for productivity and recreational uses on a continuing basis and of minimizing the potential extinction of certain other species.

During the early 1970s the USDA Forest Service was a leader in working with the problem of managing public lands to insure the maintenance of diversity. The agency sponsored open symposia (e.g. Smith 1975, Capen 1981) on scientific problems and applications and helped to catalyze an innovative period for scientists interested in exploring habitat management techniques. Two different management approaches were developed under direct influence of the economic and political constraints attendant to the land management problems in their respective regions of the United States. These two concepts were the "featured-species plan" (Zeedyck and Hazel 1974) used in the productive forests of the southeastern United States and the "area-diversity plan" (Evans 1974) used in the hardwood forests of Missouri.

In the featured-species plan (Zeedyck and Hazel 1974), species of birds or other animals (usually traditional game animals) were studied to better understand their ecological requirements and to develop a plan for forest management. The resulting plan would optimize the availability of habitat for the featured species considering other resource values in the area.

In contrast, the area-diversity concept (Evans 1974) was designed to create an optimal diversity of animals by managing land to insure the presence over time of all the recognizable habitat types in a region. The plan evolved in Missouri in a hardwood forest region in which all but the most productive forests were used for recreation and watershed protection. The area-diversity plan uses ecological diversity as a central principle and uses the treatment of blocks of land (ca. 40 ha) to maintain a landscape mosaic of different habitat types. Tracts of land are cut and even-aged forests are regenerated on the cut-over sites. The amount of land cleared in any given year is designed to initiate a sequence of tree regeneration and regrowth leading to mature forest. Such a system is very conservative in terms of how much land might be harvested in a given year.

These approaches to developing management plans, and others (Gill et al. 1974, Holbrook 1974), have evolved considerably since the early 1970's. For example, a management plan that was an area-diversity plan might use a featured-species plan on areas that harbored a rare and endangered species or an important game species (Zeedyck and Evans 1975, Harris et al. 1984). The Forest Service now uses as a matter of policy a synthesized version of the two approaches called management indicator species (Mealey

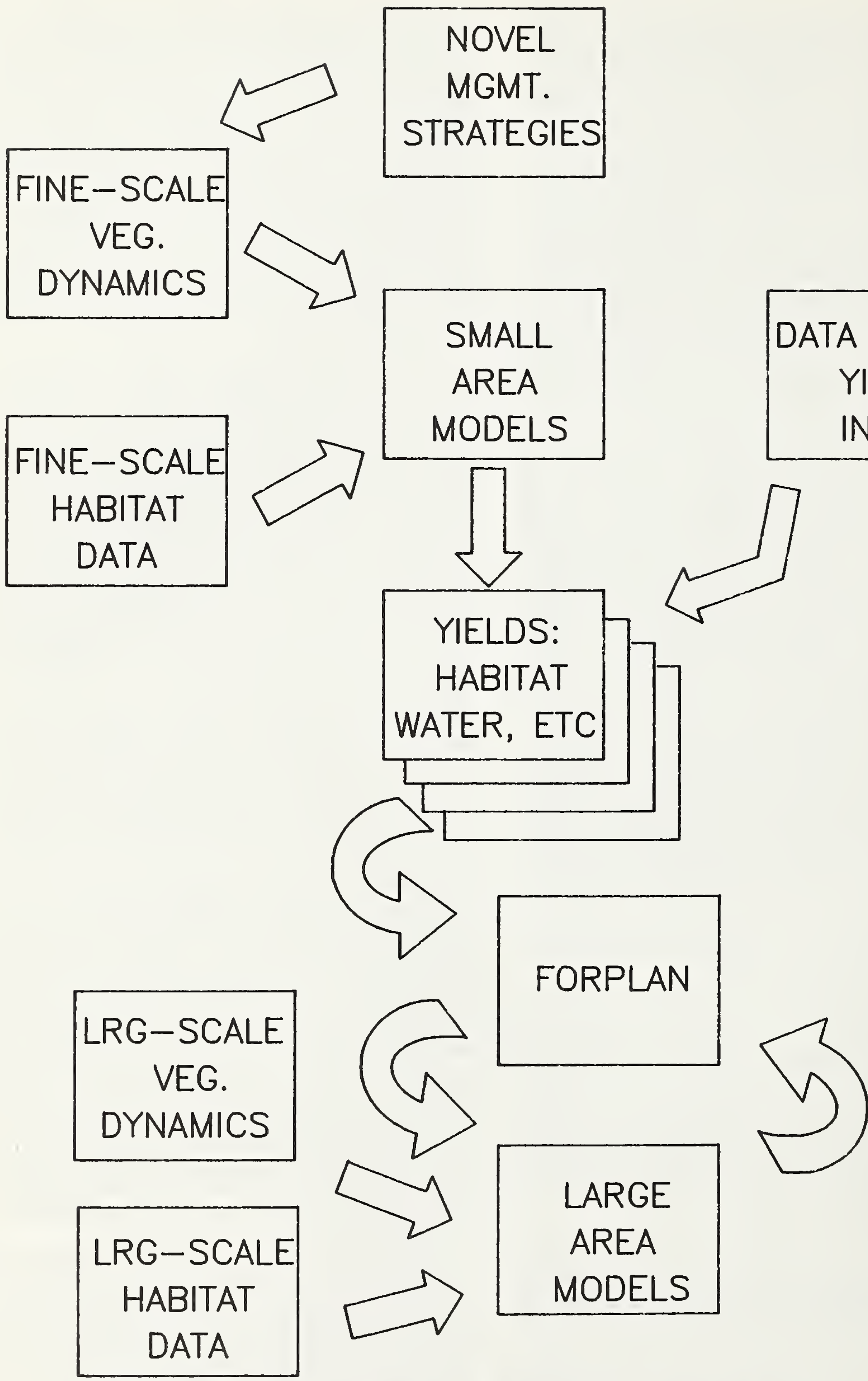


Figure 2.--Example information flows for large- and small-scale simulation as post- and preprocessors to FORPLAN. Large-scale models also could be used as preprocessors if appropriate.

and Horn 1981, Salwasser and Tappeiner 1981). Key elements of both of the approaches include the association of plant or animal species of interest with habitat and the understanding of the dynamics of habitat (and the consequent need for an active and sustained management plan). These elements can be augmented technologically using computer models to simulate the dynamics of the vegetation and using more accurate descriptions of habitat resulting from the application of modern statistical techniques. The most important aspect of these habitat management plans is that they form a background in experience and concept for a landscape/ecosystem management scheme that can be used to manage large areas to conserve diversity.

ECOSYSTEM/LANDSCAPE MANAGEMENT

The featured-species and area-diversity concepts have an important difference in scale: The featured species concept is a fine-scale technique that allows one to tailor a tract of land for the apparent needs of particular species. The area-diversity concept is a larger-scale technique that is more oriented to maintaining regional-scale diversity. There are three key elements involved in developing an ecosystem/landscape management plan for regional species diversity:

1. The ability to associate individual species with the features that make up a landscape.
2. The ability to predict the changes in the character of the landscape.
3. An understanding of the way species will respond to a dynamically changing landscape. This understanding should be both species-centered (how the dynamics of the ecosystem might effect a particular species of interest) and ecosystem-centered (how the success or failure of a given species might effect other components of the ecosystem).

Key Element 1: Associating Species with Landscape Features.

Models that relate organisms to habitats or other features of the landscapes form a diverse array of methodological approaches and a correspondingly large scientific literature. The more recent cases are dominated by statistical approaches. These cases differ most clearly in the scale in space to which the methods can be expected to apply. A dichotomy of large- (usually greater than 100 ha) and small- (usually smaller than 1 ha) scale methods can be used to frame a general discussion.

Large-Scale Approaches

For animals, there is a large repository of information that associates the abundance (or potential abundance) of a species with the condition of a large tract of land. In general, one uses a high density of a given species as strong evidence for the suitability of a given sort of habitat. This may not always be the case. For example, Van Horne (1983) proposed that habitat quality be defined in terms of fitness (an index that increases with the probability that a given individual organism will produce viable offspring) and noted several cases in which high densities in a given habitat did not necessarily show a high fitness. One such case occurs when large numbers of subdominant individuals are forced into marginal habitats by more dominant individuals during episodes of high population densities. In such instances the densities in what is marginal habitat can be misleadingly high. Such cases have been documented for small mammals (Kock et al. 1969, States 1976, Schantz 1981) and birds (Fretwell 1969, O'Connor 1981). These considerations speak to a need for more insight into dynamics of the populations as an aid to better management.

Methodologies that use presence or abundance of a species to determine habitat quality and then use such information in habitat management generally are based on correlations. Thus, a species which occurs in a habitat called "hardwood forest" provides a reasonable expectation that it might occur in a managed hardwood forest; but this expectation is based on the strength of correlations between the apparent animal abundance and the features of the gross habitat over large tracts of land.

The problems that are potentially associated with the use of correlational relationships to design management schemes to insure a maintenance of diversity sound a cautionary note and underline the need for continued studies to improve management plans. The minimal level of follow-up studies would be the continued monitoring of the managed system to determine if the management plan was producing the desired results.

Small-Scale Approaches

An alternative method of associating a species with habitat is to correlate the presence or abundance of the animal or plant with habitat features measured at a very fine spatial scale (typically 0.1 ha or less). The essential observation behind these small-scale approaches is that a species found in, say, "Oak-Hickory Forest" is not necessarily found in all parts of such a forest. The habitat of the species is characterized by the unique features of the subset of the area where individuals of the species are most often found. There is an element of capitalizing on the heterogeneity of pattern in habitat to understand in greater detail the factors controlling the distribution of a species.

These approaches explore the correlations among the species occurrence and the quantitative measures of the habitat (Capen 1981). The statistical methodologies used are often based on multivariate models that can take into account the intercorrelations that are a prominent feature of sets of habitat variables (Green 1980). Unfortunately, these methods also tend to render the results of such analyses to a form that is not easily understood by most land managers.

Key Element 2: Predicting Changes in the Character of the Landscape

Large-Scale Approaches

There are two sorts of simulators that are logically compatible with a landscape mosaic concept of ecosystem dynamics. According to this concept the expected change in a landscape over time is obtained by summing the response of many patches as simulated by such models.

Vegetation/patch simulators project the change in landscapes at the scale of hundreds of hectares and sometimes hundreds of square kilometers. The models tend to be mathematically simple compared with the individual-plant simulators that are discussed below. Markov models of landscapes are a typical example. Markov models are based upon certain assumptions in their application at the landscape level:

1. They are based on the assumption that a landscape can be divided into a set of discrete patches.
2. Change in the vegetation is expressed as a set of probabilities that the vegetation will be in some other state at some fixed time later, given the state of the vegetation on a patch at the present (transition probabilities).
3. The probabilities of change are assumed to be constant over space and time.

It is a definite advantage of the Markov formulation that the parameters are straight-forward in terms of what they represent. For example, see the work of Kessell and his colleagues who developed several models for use in landscape management of national parks in the United States, Canada, and Australia (Kessell and Potter 1980, Kessell et al. 1982). One can use remeasured vegetation survey data to obtain the transition probabilities (although it requires a considerable amount of such data to estimate the parameters of a Markov model that has very many states). In several cases, the parameters of Markov models have been estimated by inference. For example, Horn (1975) assumes that the percentage of young trees growing beneath large canopy trees of a given species could be taken as an estimate of the transition probability in a Markov model. Waggoner and Stephens (1970) provide an example of using resurvey to parameterize a Markov model for a forest in Connecticut. The current modifications in the FORPLAN Version 2 model that involve probabilistic outcomes (Johnson and Stuart 1984) could make the incorporation of Markov succession models into FORPLAN feasible.

Small-Scale Approaches

Individual-plant vegetation simulators in current usage today also often are developed with the view that the landscape can be considered to be a mosaic of patches where each patch can be thought of as having some description about the type of vegetative cover. Unlike Markov models, these small-scale models are constructed to simulate with some degree of detail the ecological interactions within each patch. Often, the models compute the dynamics of individual plants within each simulated patch and produce predictions that are quite detailed. As an example of a small-scale vegetation simulator, one might consider gap models of forest dynamics (Shugart 1984).

Gap models function by computing the diameter increase of each of the trees growing on a small simulated plot around 0.1 hectares. The trees are increased in size annually. Mortality of the trees on the plot and the birth of trees are stochastic functions that are also applied annually. The fundamental approach in developing these models was outlined by Botkin et al. (1972). Shugart (1984) provides a detailed explanation of the model assumptions and relates the behavior of several gap models to modern ecological concepts of forest dynamics. The models do not require elaborate data sets for parameter estimation. The philosophy that underlies the development of gap models is to represent the dynamics of the forest using general equations that can be obtained from basic physiology, morphology and silvics of trees. The models have been successfully tested against independent data in several cases and appear to do a reasonable job of predicting the pattern and dynamic change in forests.

Another example, which is interesting from the standpoint that an ecological objective was being sought, is provided by Rice et al. (1985). The model was developed as part of a project with the objective of achieving a higher species diversity on dredge spoils in the Colorado River than any naturally occurring riparian vegetation in Arizona. The objective was achieved and the model was used to assess changes in presence and abundance of about 70 species to changes in management.

Both the large- and small-scale models have certain advantages and disadvantages in terms of their application to landscape management problems. In the example model types above, the gap models run more slowly on a computer and require a research scientist with some training in ecological modeling in their development stage. Gap models can be used to produce a detailed description on each of the plots that sample a landscape and often have a sufficient degree of realism that they can be used to predict the response of a landscape to a novel change (e.g. climatic change, air pollution stress, change in wildfire regime). Markov models are computationally fast and easily set up on most computers. They can be used to generate dynamically changing maps. Markov models require a considerable amount of data for parameter estimation, particularly in complex systems and they have no internal mechanisms in their formulation that would allow them to be expected reasonably to predict system response under novel conditions.

The most logical evaluation of the question, "Which model should be used to estimate yields for FORPLAN?" is to say, "Both." The two modeling approaches are compatible and a wise approach to using the models to predict landscape change would be to develop a nested set of models with the gap models being used under novel conditions and the Markov models being used for the large scale projection of landscape change. The gap model output is more compatible with the scales used in

multivariate statistical studies of animal habitat selection; the Markov approach leads one to attach more general habitat descriptions of the sort used in field guides to suggest where a species might be found.

Key Element 3: Organism and Landscape Interactions.

The venerable concept in ecology, that landscapes can be viewed as dynamically changing patches, (Aubreville 1933 and 1938, Watt 1925 and 1947, Whittaker 1953) has recently emerged as a strong unifying concept in forest ecology (Bormann and Likens 1979a, 1979b; Whitmore 1982; Shugart 1984). Bormann and Likens (1979a) noted that forest ecosystems "... may be visualized as an array of irregular patches composed of vegetation of different ages. The structure of the ecosystem would range from openings to all degrees of stratification, with dead trees concentrated on the forest floor in areas of recent disturbance. The forest stand would be considered all-aged and would contain a representation of all species, including some early successional species, on a continuing basis." Watts' (1947) classic paper documents this same concept for a wide range of ecological systems including not only forests but bogs, heathlands, grasslands and alpine communities.

The use of multivariate statistics to quantify the relation between organisms and habitats fits naturally with the mosaic concept of a landscape. This is a consequence of research scientists designing multivariate techniques which attempt to capitalize on the fine scale heterogeneity of the landscape to provide insight into patterns of habitat selection. For this reason, the samples used to provide the basic data for the multivariate analysis often are collected with the explicit goal of having spatial dimensions that are analogous to those of the pattern of the spatial mosaic and thus match the scale of the elements of the landscape mosaic.

If the scale of a landscape simulation model and the scale of the data used to calibrate a species/habitat relationship are compatible, then one can meld the two to simulate the dynamics of populations in response to a dynamically changing landscape. Table 1 summarizes the relationships of large and small scale modeling tools to the three key elements involved in developing ecosystem/landscape management plans for species diversity.

There are potential errors in using such an approach that could stem from several sources. Errors estimating the nature of the association between the habitat and the species presumably can be minimized by increased sampling. Errors resulting from the inability of a landscape model to exactly reproduce the conditions on the modeled landscape is another primary source of error that can probably be minimized by a rigorous model-testing/model-reformulation protocol. A third important source of errors could arise from important interactions not included in the model. These errors could be because of spatial effects not included in the model (dispersion of a species across a landscape might be so slow that it prevents the colonization of newly generated habitat before it disappeared because of successional processes.) Another source of the errors outside the model formulation could be interactions with other species that are also using the landscape (competition, predation, parasites harbored in one species infecting another species). Control of these sources of error require a concerted effort in basic ecology particularly focused on environment/organism and organism/organism interactions.

THE RELATIONSHIP OF ECOSYSTEM/LANDSCAPE MANAGEMENT TO FORPLAN

FORPLAN models used for forest planning typically depict vegetation dynamics at a large scale, while spatial interactions may or may not be handled depending on the model. Before constructing a FORPLAN model, the relationship of indicator species to habitat is determined outside of FORPLAN and then the relationships are incorporated into the model to the extent possible. Solutions from FORPLAN show how habitat, or indicators of habitat, change through time. Habitat changes may be a consequence of vegetative treatment for other resource benefits or result from direct habitat improvement projects. Models of the type described above (mosaic/patch simulators) can be used to help predict the consequences of such management activities on wildlife habitat including some of the spatial effects. For example, under novel conditions, such as innovative management techniques, the small scale models can be used to estimate yields and effects. Similarly for areas where empirical data is weak or missing, results from such models can be used as proxies for actual data. However, large scale models can be used when circumstances are better understood. Model results can in turn be input into FORPLAN and can be used as part of the criteria for determining the optimal solution for a particular plan alternative. Under this scenario the input would be in the form of integrated production functions, i.e., yield tables, for management prescriptions (See Mealey et al. 1982 and Stage et al. 1986 for examples of how this might be accomplished in the forest planning context, fig. 2).

Approaches to resource integration such as this parallel what is happening on many national forests during plan implementation, although computer models are not always used (Sweeney 1985, Holthausen and Dobbs 1985, Benson and Landenslayer 1985). The difference in what is being described here is that the integration and some of the spatial analysis is done before choices being entered into the LP model (called coordinated schedules). Several forests have tried this approach on all or part of their land base. Although this approach requires more work before running FORPLAN, there are several advantages, some of which address the philosophical criticisms presented at the beginning of this paper. It is important to realize that some of the advantages such as reduced FORPLAN model complexity are achieved at the expense of increased analysis before FORPLAN.

The criticisms related to model size can be resolved, because far fewer columns are needed to represent timber timing choices. Presumably, all the analysis done during this round of planning will provide insights into logical timber

Table 1.--The relationship of large and small scale modeling tools to the three key elements involved in developing ecosystem/landscape management plans for species diversity.

Key elements	Large-scale	Small-scale
Associate species with landscape	Correlations based on presence or abundance with monitoring to help verify correlations	Multivariate Statistical models with intercorrelations
Predict changes in the character of the landscape	Markov models with constant probabilities	Mechanistic ecological interaction models (e.g. GAP models)
Predict interactions of the species with its landscape	IF the scale of the species habitat relations are the same as the simulation model, THEN the dynamic changes of population as a function of changing landscape can be simulated.	

management regimes for the next round of planning. In addition, the coordination of harvests within an area is likely to reduce the need for so many timing combinations. Furthermore, fewer constraints are required to achieve spatial feasibility, because spatial feasibility is determined for prescriptions before they are included in the model.

Johnson (1983) captured the essence of the major problem with coordinated schedules:

> "The reduction in model size gives some clue about a disadvantage in representing scheduling choices on an area basis. These choices are time-consuming to construct and require considerable imagination. Probably not all of those that might be developed will be represented in the problem. Therefore, achievement of the objective specified for the problem may be reduced not only because of the constraints implied by the standards that must be met, but also because important choices were left out."

Furthermore, there is a need for the decision variables to be selected in their entirety in the optimal solution. LP algorithms will not necessarily satisfy this need and therefore special techniques may be needed to obtain sensible solutions (Johnson et. al 1986). Finally, in the analytic framework used by the Forest Service, where economic tradeoff analysis is stressed, it is difficult to show the cost of constraints that are integrated into decision variables.

Forests that have been successful with coordinated scheduling have used it only on portions of their forest and for the early part of the planning horizon where they have a good notion of a reasonable range of choices. Such a compromise approach has two advantages, one being less work for the ID Team in creating the schedules, and the other making realistic solutions easier to obtain using LP. LP solutions are more easily obtained because acres for which coordinated schedules are not used have more scheduling flexibility which allows constraints such as nondeclining yield to be more easily satisfied. Furthermore, if schedules are coordinated for only the first part of the planning horizon additional scheduling flexibility is permitted later in the planning horizon. A compromise coordinated scheduling approach fits well with the intent of forest planning, which is to "evaluate immediate decisions with an assessment of the long term consequences" (Barber 1986).

Models formulated this way are simpler and less expensive to solve, therefore, more analysis can be done. Solutions are easier to check for reasonableness and to disaggregate to the ground because integrated, implementable prescriptions are entered into the model. Perhaps the biggest payoff, however, is the enhanced ability to comprehend and explain the solutions to management and the public. The ability to see the selected schedule for an area would greatly enhance this understanding. Finally, the ability to better understand the results will lead to them being used by decision makers and managers, the final goal of modeling and analysis.

SUMMARY AND CONCLUSIONS

Such a revised approach to formulating FORPLAN models has potential to improve the analytic results and their utility. Using a combination of simulation pre- and post-processors with an LP land allocation and activity scheduling model allows the analyst to use the strengths of both tools to address all the necessary ecological facets, while minimizing the weaknesses of each modeling approach. However, this alone will not suffice. It is also necessary for ecologists and scientists working with resource managers to explain the significant production functions necessary to make management decisions. NFMA states in Sec. 6 (g)(3)"(c) insure research on and (based on continual monitoring and assessment in the field) evaluation of the effects of each management system to the end that it will not produce substantial and permanent impairment of the productivity of the land." This statement provides the impetus for examining ways to efficiently determine and modify production functions using new systematic approaches to monitoring (Walters and Hilborn 1978, Sisler and Jameson 1983, Holling 1978). The challenge is to capitalize on the continuing management experiments

being conducted by the Forest Service such that better management decisions can be made in the future.

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A Discussant's View of an Ecological Evaluation of FORPLAN

Linda A. Joyce[1]

Abstract.--An ecological evaluation of FORPLAN involves an evaluation of FORPLAN against the modeling objectives described in the National Forest Management Act, and an evaluation of the ability of FORPLAN and the actual forest models to portray the ecosystem behavior of concern in NFMA. Improvement of the modeling process within land management planning must include a consideration of the scale of the planning problem, modeling approaches appropriate to the scale, and the feasibility of implementing the modeling approach in land management planning.

The critique of FORPLAN from an ecological perspective is a difficult task, and Shugart and Gilbert (1987) have presented an excellent paper towards that goal. The purpose of this paper is to discuss further these issues:

1. the basis of an ecological evaluation of FORPLAN;
2. the technical considerations using FORPLAN to model ecosystem dynamics;
3. reflections on improving FORPLAN.

The Basis of an Ecological Evaluation of FORPLAN

Objectives of the Analytical Tools

An evaluation of FORPLAN from an ecological perspective presumably would take the set of objectives which spawned the development of the modeling system of FORPLAN, the array of actual models constructed using FORPLAN, and evaluate the ability of these systems to portray the ecosystem behavior of concern in the objectives. Uncovering the specific objectives which prompted FORPLAN's development leads to the National Forest Management Act (NFMA). When the Act is used to determine the objectives for the analytical techniques, one must conclude that the Act is vague. Woven throughout Shugart and Gilbert's (1987) paper is a persistent struggle about just what the true objectives of the analytical tools directed by NFMA were.

The law was written when no one knew precisely what forest planning would encompass. Diversity was understood to represent stability at the time the act was written. Over time, our interpretation of words in the act, our understanding of Forest Service land management planning, and our understanding of ecological theory have changed. Different words in the law were **key words** and become **key words**. Today, more factors than diversity have been identified as contributing to stability in ecosystems, for example. A current evaluation of the initially chosen analytical techniques will be based on this evolving perspective of land management planning and scientific theory.

As outlined by Shugart and Gilbert (1987), the Act implies that the analytical tools must be able to:

1. Consider sustained yield of all multiple uses,
2. Coordinate all resource management,
3. Evaluate alternative management systems with economic and environmental effects, and
4. Address the diversity issue, although no model was specified in the Act.

Specifically, NFMA requires that the **forest plan** must show that these factors have been weighed reasonably in the management decision. This "reasonableness" will be defined, most likely, in terms of a "record," which will prove to a judge, that all the relevant factors have been weighed by the decision maker (Fairfax 1980). To quote Fairfax, "Judgment based on the wisdom of experience is not legally reasonable." Shugart and Gilbert assume in their critique that the forest plan must show this reasonableness by quantifying the entire management selection process.

The authors portrayed large model development occurring in situations where there was no intuitive solution. I suspect that forest managers have the intuition to manage wisely. To propose any other answer would suggest that the Forest Service promoted poor managers or that the Forests were in trouble long before NFMA. What appears to be happening is that we are trying to quantify that intuitive answer to prove its adequacy to others. When the number of groups participating in the planning process increases, the number and diversity of intuitive explanations increases also. For example, Shugart and Gilbert point out two management styles: proactive and reactive.

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Models developed to examine ecosystem dynamics versus obtaining consensus on opposing environmental views have been very different in practice. The former have been highly detailed complicated models, such as the IBP Biome ecosystem models (Innis 1978). The latter have been largely intuitive models where the computer was used to quantify and condense those differing perspectives on environmental management, such as the Adaptive Environmental Assessment models (Hollings 1978). Shugart and Gilbert conclude that the analytical tools needed to support the NFMA fall within the category of models examining ecosystem dynamics. By the end of their paper, their struggle with objectives is resolved in development of two analytical needs that must be met in any improvement of the FORPLAN system. The analytical tools must be able:

1. to help the resource manager understand and predict ecological responses to managed and unmanaged conditions;
2. to help managers choose the best management alternative to achieve multiple use objectives based in part on ecological effects.

Ecosystem Behavior

If we take these objectives as the starting point to critique FORPLAN, two questions arise about ecosystem behavior:

> Must the resource manager, or the analyst, understand and predict **all** ecological responses to managed and unmanaged conditions?
>
> What ecological effects must be quantified in order to choose the best management alternative to achieve multiple use objectives?

When NFMA was written, diversity was a key ecological idea that was used to ensure the stability of the ecosystems on national forests. Shugart and Gilbert cast up what has become important in modeling forest dynamics using FORPLAN. Presumably, if FORPLAN or the forest models were able to simulate these facets of ecology, then one could conclude that FORPLAN/the actual forest models were appropriate tools to model ecosystem behavior. FORPLAN is different from the actual forest models. A tremendous responsibility rests with the analyst in the development of the actual structure of the forest model. If FORPLAN can handle any of the above ecological facets, it is not guaranteed that the actual forest models modeled the ecological facet. This difference is critical. If one forest found a way to model these ecological facets using FORPLAN, then FORPLAN can be used.

If we look at the author's conclusions, FORPLAN, under a set of assumptions, can handle these ecological facets, as shown in table 1. A yes implies a suite of assumptions, not the least is model size is unconstrained, or the number of timber alternatives is reduced from all possible, etc.

Table 1.--FORPLAN's ability to model the ecological facets.[1]

FACET	Ability
Nonlinearities	YES
Time Scales	YES
Multiresource Interactions	YES
Spatial	YES/NO
Variations and Model Error	NO
Uncertainty	NO
Succession	YES
Dynamic Ecological Processes	MAYBE
Vertical Diversity	YES
Land stratification	YES

[1]Given many assumptions such as model size is unconstrained or timber alternatives are reduced.

Technical Considerations When Modeling Ecosystems Using FORPLAN

Nonlinearities

The ability to describe non-linearities in ecological relationships is the well-worn criticism of the application of linear programming to ecosystems. These problems have been discussed by others in these proceedings. It is probably safe to conclude that LP models can represent nonlinear responses under certain circumstances: when the output response increases as management intensity increases on a per acre basis; when the output response changes as the number of acres change.

An additional problem occurs in the building of the actual model using the structure of LP, not in the structure of the LP model itself. Non-linear functions of management activities are difficult to convert into approximate linear relationships. The model builder's perception of the environmental system will affect the scale of the forest model. The scale of the forest model will affect the ecological processes critical to be modeled. Some of these processes will be nonlinear. Shugart and Gilbert acknowledge that LP structures are not common in ecological modeling. Thus, little guidance is available to offer the model builder ways to incorporate nonlinearities into the LP structure.

As others have noted, there is an additional problem associated with nonlinearities in ecosystems--spatial patterns affecting the production response. The significance of this spatial patterning is a function of the scale of the model (Milne 1987). Scale also enters into the discussion of the LP models ability to model the resource response to catastrophes. For example, on any scale, the ecological responses to road building can be described as a catastrophe. This is not to suggest that technology can fix everything or that catastrophes do not occur in ecosystems.

Nonlinearities in ecosystem processes are a function of the scale at which they are examined. The model builder's perception will affect the level of scale to be modeled, and, therefore, the amount and difficulty of nonlinearities that must be modeled.

Multiresource Interactions

Linear programming models are the intersection point for economic values and ecological production in quantifying the management decision process, and multiresource interactions. From a theoretical perspective, the use of LP models can be justified on the basis that the LP model traces out an approximation of the production function of the forest. Choices between resource management practices can be made considering production spaces, and the production frontier.

Shugart and Gilbert state that, "It is not at all clear that the management strategy for optimizing money developed by using a FORPLAN model, under a constraint of maintaining a given level of animal species diversity, would even resemble the optimal strategy for optimizing diversity under the constraint of producing a certain cash flow." In theory, if the cash flow constraints were defined similar to the money functions optimized, the resource outputs would be the same for both LPs. The total number of management prescriptions in the LP approximates the production space of the system. If the number of management prescriptions is fewer than the total number feasible, then the LP will poorly approximate the production space of the forest. One must ask would the management prescriptions be different under the two scenarios the authors proposed because of omissions of necessary prescriptions from the model structure? Does optimization of species diversity conjure up a different perception of the necessary management prescriptions than if the forest were managed to optimize cash flow? If yes, then the problem is in the model formulation, because the incorporation of management prescriptions has been biased by a singleness of the goal and the production space has only partially been described in the LP.

Although ecologists agree that the input of labor and capital change the function and structure of the ecosystem, ecosystem simulation models rarely have quantified the impact of management and the mitigation necessary to respond to a change in the structure or function of ecosystems. Ecosystem models often describe the system dynamics under management, such as harvesting, or clearcutting. But, rarely, is the model used to determine the type of management action necessary to mitigate the undesirable aspect of the management action. We must ask the question, "What is the role of ecological simulation in describing the production space of the resource system?" Is the idea of a production space or the production frontier fully understood by the resource specialists/ecologists when the actual forest model is constructed?

Little ecological theory has been incorporated in the development of the economic joint production theory. The assumptions underlying the theory have not been tested using ecological theory. Economists assume that an ecosystem functions in a manner similar to a firm. The underlying structure of a firm is known with certainty, but the underlying structure of ecosystems is not known with certainty. Further work is needed here to examine the implications of these assumptions.

Spatial and Temporal Scale

The spatial and temporal dimension of ecological relationships is a difficult concept to incorporate into the actual forest models. This dimension becomes especially important when the management action disrupts a rhythm of resource production which assumed a certain spatial or temporal distribution, previously unrecognized.

The most obvious representation of the spatial dimension is the analysis area. As the authors point out, analysis areas are delineated upon the interaction of several ecological components, such as soils, relief, climate and vegetation with the implicit assumption that these derived areas reflect differences in potential response to management and resource productivity. Determining the yield coefficients which represent resource production within these analysis areas significantly affects model adequacy in representing ecological processes.

The spatial and temporal character of the land changes under management and varies by resource. When a function such as mining enters, the historical ecological components may have nothing in common with the future ecology of that site. To resolve these problems, we become "splitters" in land classification rather than "lumpers." This forces the scale to finer and finer levels, and the LP model to larger and larger sizes. This process assumes that a land taxonomy will provide the basis on which the system will function under management.

Once the fine grid of analysis areas is defined, model coefficients are derived to represent resource production on the analysis areas. Model coefficients will have inherent variability, and could be described using inventory measurements. However, this variability maybe significantly different across analysis areas or maybe a function of the land classification. The significance of scale is being recognized as increasingly important (Allen and Starr 1982) and may have a substantial contribution in sorting out this land classification problem.

While the implications of scale in quantifying ecological processes are evolving, scale is also important in economic considerations in FORPLAN. The definition of management prescriptions involves a consideration of what activities ought to be included into the model. The scheduling of harvest involves many activities that are not specifically incorporated into the LP model. These activities are deemed of little importance in the scheduling of timber at the analysis area level or forest level.

Residual Unpredictability

Uncertainty in ecological processes is difficult to incorporate into a static model. Unlikely events occur in ecosystems and these events impact the survival of plant

and animal populations. As the authors point out, the difficulty is in realistically representing the consequences of uncertain events. The ecosystem can be seen moving from one equilibrium to another equilibrium. Risk analysis prior to the LP model has been used to reconcile uncertainty in minimum viable populations by determining the constraint necessary to keep the system from moving out of the desired equilibrium (Salwasser et al. 1984). This approach works when the consequences of the uncertain event to be avoided can be described, extinction of a population or species, and the LP model contains the necessary variables which must be constrained, habitat variables. This approach does not work for events, such as floods or pest outbreaks. As Hof (1987) has discussed, the LP framework may not be the appropriate tool to model these events.

Once the FORPLAN model is constructed, all aspects of the structure of system appear to be **known** with certainty. That they are accounted for with certainty is another problem. What is meant here is the uncertainty that cannot be explained, the ignorance of processes that are reflected in the variability and that cannot be linked to a casual explanation. This type of uncertainty, called "residual unpredictability" by Walters and Hilborn (1978), affects the ability of the model to project.

A long line of modelers, including some ecological modelers such as Karplus (1975) and Walters and Hilborn (1978), have long urged acceptance of the uncertainty in ecological systems, or rather, acceptance of our inability to precisely model ecological systems. Walters and Hilborn (1978) described current ecological management as a passively adaptive discipline:

> "We observe disturbed systems, synthesize sometimes elaborate models, and conduct optimization exercises which pretend that our actions will not affect the way we observe and learn in the future. Eventually, with luck, we are able to devise optimal feedback policies. These specify the best behavior in the face of a residual unpredictability whose probability characteristics we have discovered through experience. Along the way we waste a lot of time trying to understand how this residual variability arises, forgetting that we usually cannot do anything about it."

Our understanding of ecological responses and our ability to quantify some of the components of that residual unpredictability have increased over time. To say that we usually can never do anything about that uncertainty might be a strong statement. However, it is equally absurd to conclude that the residual unpredictability does not exist, as we do in models which have a fixed structure.

The model represents the best quantification of the system. The impact of the known variability on this projection estimate must be ascertained to further reduce this component of the projection variability. Dixon and Howitt's (1979) work in California showed possible approaches to model refinement using control theory. It is more difficult to assess the impact of the residual unpredictability of the projection estimate. The LP model structure makes it difficult to incorporate this uncertainty. It is difficult to link the movement of ecosystems from an equilibrium characterized by a continuous smooth surface to a new equilibrium in which the surface is not continuous (Walters 1986). To demand this from a planning model may be too large of a task. To ignore it is impossible. The middle ground may be to devise an approach to incorporate the uncertainty so that it provides information which can be used to redirect the change in the model. Sisler and Jameson's (1983) work on monitoring has shown a feasible approach using control theory.

Improving the Ecological Content of FORPLAN

Shugart and Gilbert (1987) propose an interactive relationship between FORPLAN and Forest Simulators shown in figure 1. This approach has much utility. It addresses the problems of scale, incorporates some measure of uncertainty, and offers the potential of reducing the size of the final forest-level model.

Perhaps, the most important point of this proposed improvement is the recognition of scale in quantifying ecosystem dynamics. What Shugart and Gilbert have proposed is a modeling system tailored to describe ecosystem dynamics at more appropriate levels of scale by appropriate modeling techniques. What will this approach require?

First, it will require that species/habitat relationship models be constructed for selected species (or indicator species, etc). This requires multivariate data linking the species with the habitat. Further, the multivariate data describing the habitat must be of the same type of the data available in the vegetation/patch simulators.

Second, it will require that vegetation/patch simulators be constructed for forest types on a forest. Again, this requires data on forest management and tree dynamics. This requirement may not be too difficult to accomplish for the individual plant vegetation simulators, because these use much of the forest managers' intuitive experience along with available data.

This approach will rely heavily on the choice of patch size. This becomes the indivisible unit, like analysis areas, and all forest dynamics must be described in terms of this size. It also will require inventory data to construct the species/habitat relationship models. Ultimately, a link between the needs of the analytical tools and the inventory would improve models.

Conclusions

Shugart and Gilbert proposed three criticisms of using large models: a distrust arising from model complexity--small is beautiful; the difficulty of comparing intuition and model results; and the computer costs involved in running models. These criticisms can be restated in a broader framework: the role of model abstraction in land management planning. Ecosystem behavior is known only in part, and never with certainty. The ability of the analyst to abstract the environmental system using FORPLAN is crucial to the success of the actual forest model in describing ecosystem behavior.

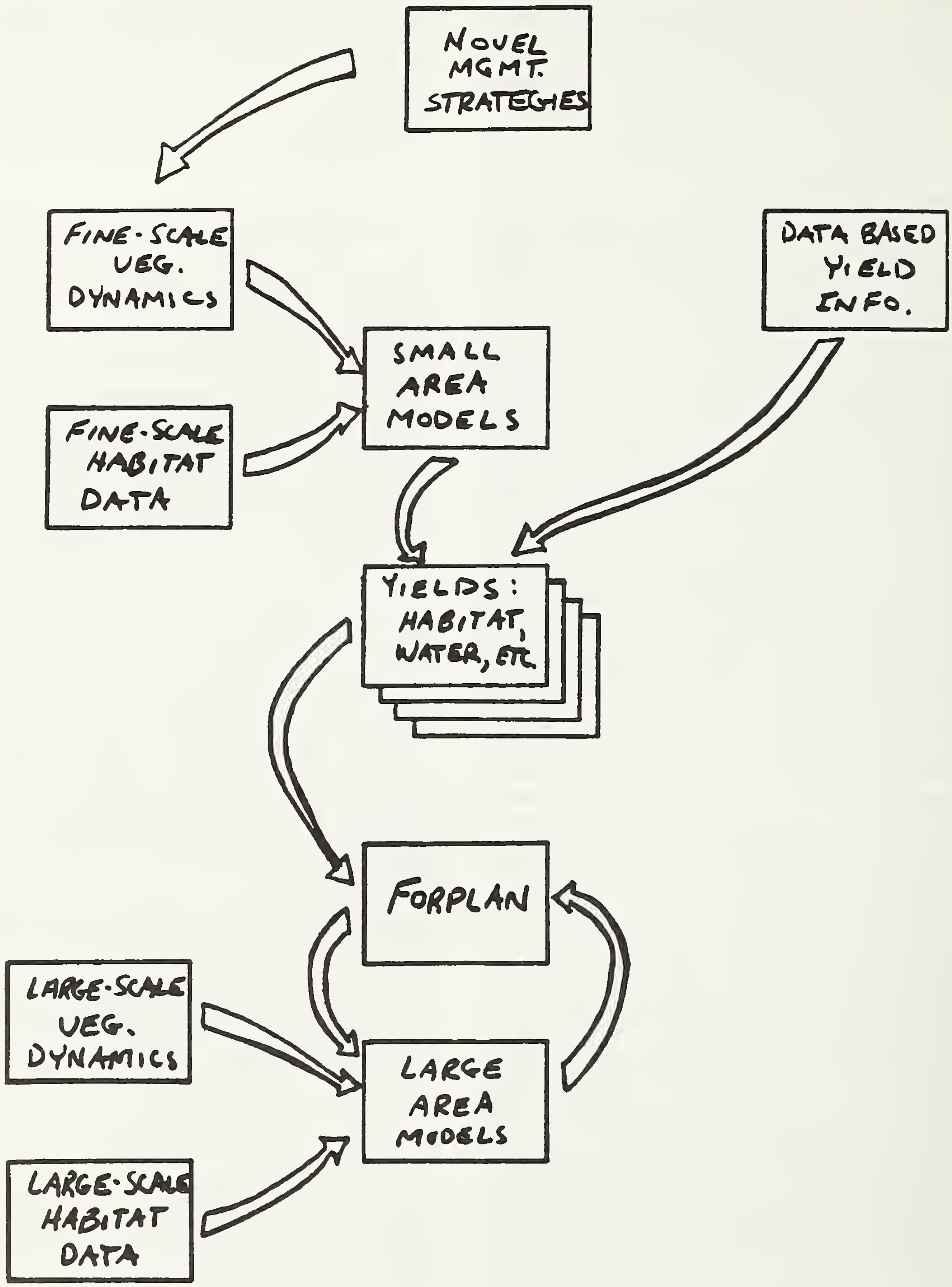

Figure 1.--Proposed improvements in the modeling systems used in land management planning (Shugart and Gilbert 1987).

While I agree with Shugart and Gilbert that the objective of model abstraction in land management planning is to allow the exploration of resource production potentials using ecologically sound management, must this entire process be quantified in the forest modeling system? What aspects of the ecological system must be abstracted in the modeling part of the planning process?

What did NFMA imply about the objective of the analytical tools? Were the models to allow resource managers to reach consensus in the public involvement process, or were resource managers to use the models to gain insights into the production space of the system. What has FORPLAN done? I believe that FORPLAN attempted a difficult goal: to be both types of models.

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Hierarchical Landscape Structure and the Forest Planning Model: Discussant's Comments

Bruce T. Milne[1]

Abstract.--Special strategies are needed for building models sensitive to the hierarchical structure of landscapes. Such hierarchical models may be effective for extrapolating from fine- to broad-scale predictions. In some applications, landscape dynamics may be simulated using enhanced Markov models, especially where the effects of neighboring patches are relevant. Combinations of geographic information systems and Bayesian models of wildlife habitat offer a powerful means of linking FORPLAN results to the ground.

Shugart and Gilbert (this volume) raise many considerations regarding the application of FORPLAN to resource management in the National Forests. Their review covers two general topics: (1) philosophical considerations stemming from the application of large, complex models, and (2) ecological ramifications of the assumptions and algorithms of FORPLAN. These topics are linked by the constraints that a particular paradigm, either philosophical or ecological, impose on the design and implementation of a model.

Here, my comments emphasize the structural aspects of landscapes. First, I comment on the complex hierarchical spatial structure of landscapes, thereby highlighting an alternative paradigm which may prove useful in landscape planning. Second, I suggest several modeling strategies reflecting the hierarchical structure of landscapes. These comments were prompted by Shugart and Gilbert's awareness of scale effects implicit in the "area-diversity" approach (Evans 1974) and the "featured-species plan" (Zeedyck and Hazel 1974). The application of FORPLAN in a spatial context may require an understanding of landscape heterogeneity and structure which change predictably with scale.

Hierarchical Landscape Structure and Model Complexity

A growing interest in landscape ecology has prompted ecologists to view ecosystems in a spatial context (Naveh and Lieberman 1984, Risser et al. 1984, Forman and Godron 1986). Landscape studies emphasize the effects of heterogeneity on the flow of organisms and resources between ecosystems. Of primary interest are the relationships between the spatial and temporal scales at which ecosystem processes vary.

Urban et al. (1987) develop a fundamental relationship between the spatial and temporal extent of landscape entities; a relationship first described by Delcourt et al. (1983), but anticipated by Shugart and West (1981). Specifically, small landscape entities, such as canopy gaps created by tree falls, have a very short life span, while landscape features spanning hundreds of hectares persist for much longer periods of time. Therefore, the landscape is viewed as a hierarchy (Allen and Starr 1982, Allen et al. 1984), with small, dynamic entities layered over large, slowly changing entities. The static nature of large encompassing entities forms a constraint on the behavior of small entities.

Foresters recognize this hierarchical pattern at all levels. Each Forest is unique at the continental scale, most likely because major environmental factors such as geological features, precipitation, temperature, and insolation vary complexly throughout the United States, providing a unique combination of conditions at each Forest. Within Forests, topographical, geological, and historical patterns create unique conditions among watersheds, thus constraining the types of forests possible within these smaller regions. Environmental constraints are the slowly changing conditions of large entities within which small landscape elements exist.

Consistent changes occur in the structure of landscapes as a function of scale for areas about the size of a typical National Forest. Here, landscape "structure" is the "spatial relationship among the distinctive ecosystems or 'elements' present" (Forman and Godron 1986), where elements include common entities such as meadows, streams, ponds, and wooded patches. The scale-dependency of landscape structure means that landscape characteristics (e.g., the diversity of landscape elements) vary with the spatial scale used to make the measurements (fig. 1). The slope of the relationship is constant for a given landscape (within a specific range of length scales). Thus, the slope of the line is a "scale-independent" (Mandelbrot 1983) characteristic of a landscape. This relationship reflects the hierarchical arrangement of small, dynamic patches within large, slowly changing patches, such as entire watersheds.

Scale-dependent landscape structure suggests a possible limitation of FORPLAN when applied in a spatial context (e.g., Armel 1986, Ryberg and Gilbert 1986). A scale-

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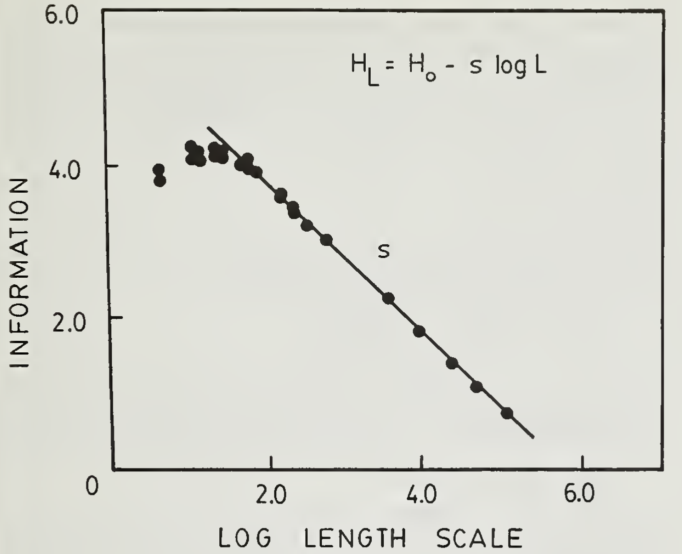

Figure 1.--The diversity of landscape elements present (e.g., forests of various types, clearings, streams) in an approximately 22,750-acre forested landscape in New Brunswick, Canada. Diversity, measured using the Shannon-Weaver Index, varies with the spatial scale at which measurements were made. Broad-scale measurements were based on aggregations of data available at the finest spatial scale. Only the slope of the curve is independent of the spatial scale.

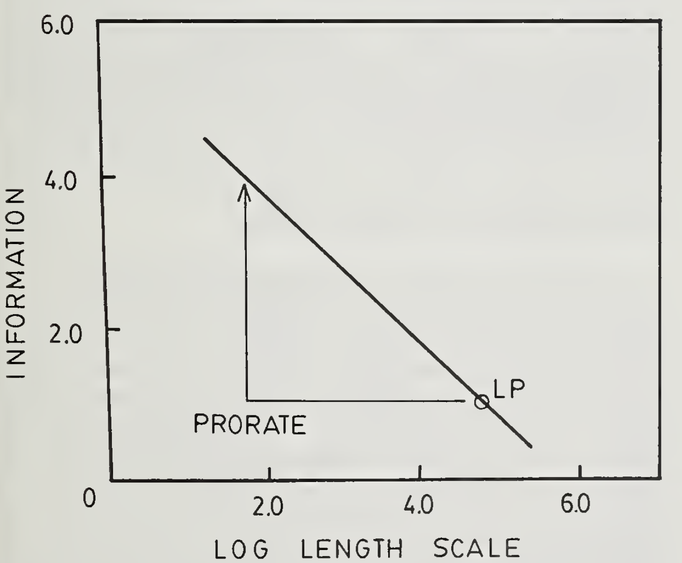

Figure 2.--Scale-dependent landscape structure may preclude prorating the predictions made at one scale to other scales. Here, the diversity of landscape elements varies with spatial scale (fig. 1). Therefore, specifying a certain diversity level at one scale as a constraint in the FORPLAN linear programming module (point LP) may result in drastic underestimation of diversity when the results are prorated to finer scales. The appropriate diversity level at each scale is determined by the slope of this relationship for a particular landscape. Here, broad-scale measurements are based on aggregations of data available at the finest spatial scale.

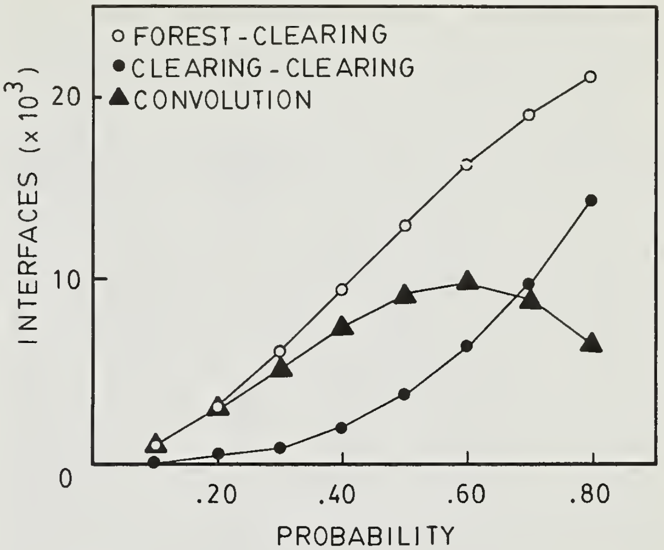

Figure 3.--The numerical difference (convolution) between (1) the number of clearcut-to-forest interfaces and (2) the number of clearcut-to-clearcut interfaces in a forest modeled as a random percolating network. At approximately 60% cutting the proportion of clearcut-to-clearcut interfaces begins to approach the greater portion of the total interfaces. Aggregation of data at different scales may shift the modeled landscape along the abscissa, thus changing the interface consequences predicted from percolating network geometry.

dependent relationship may be anticipated for both the parameters and yield streams of FORPLAN, just as the diversity of landscape elements may change with the scale at which measurements are made (fig. 1). A major discrepancy between the predictions of the model and the intended prescription (specified by the National Forest Management Act) may occur when the results are applied to the Forest as a whole. For example, if species, or landscape, diversity in an approximately 40 ha area is used as a constraint to determine yield or profits, application of the model's predictions may be inappropriate when applied to a different spatial scale, such as the entire forest (fig. 2). At the very least, prorating diversity values to broad areas without consideration of scaling relationships may degrade the integrity of the landscape as a whole.

Effects of scale-dependent structure need to be considered when data are aggregated at broad scales to reduce the complexity of the matrix entered into the linear programming module. To see why, consider that spatially complex landscapes may be represented as "percolating networks" (*sensu* Orbach 1986) exhibiting truly remarkable properties. The simplest percolating network is a set of points on a lattice, with the probability of a point being present determined by an arbitrary threshold, $0 \leq p \leq 1$. If vacant points represent clearcuts, and occupied points are viewed as forest, then a dramatic effect on the number of potential interactions between forested and cleared land is associated with the critical probability of 0.5928. Surprisingly, when the probability of clearing is $\geq$ 0.5928, there will appear a cluster of cleared areas so large that it spans the width of an infinite plane (Orbach 1986). Also at

that threshold, the relative number of interfaces between forest and clearcuts begins to diminish compared with the interfaces between clearcut patches (fig. 3).

Granted, the average density of clearcuts is rarely, if ever, equal to 59%. However, the aggregation of data at different scales, to reduce the complexity of the matrix input to the linear programming routine in FORPLAN (Barber 1986, Navon et al. 1986), may alter the consequences of percolating network geometry for estimations of yield at broad spatial scales. This occurs because a landscape is finite in area, and aggregation at coarse scales may result in finite clusters because of "sampling" effects which occur at coarse grid sizes. Therefore, the interfaces between large landscape entities (some of which result from the management regime) may obey the relationship in figure 3 based on a different probability value than the original fine-scale percolating network. Aggregation of data at different scales is an effective means of reducing model complexity, although it may drastically alter the interactions occurring among extensive landscape entities, such as watersheds.

In summary, landscapes have a hierarchical scale-dependent structure. Small entities exhibit rapid changes compared with large entities. As a result, broad-scale features (e.g., mountain ranges, watersheds) form the long-term context for smaller entities, such as clearcuts and canopy gaps. A growing interest in spatial applications of FORPLAN (Armel 1986, Ryberg and Gilbert 1986) suggests that special strategies are needed for building models sensitive to the hierarchical structure of landscapes. Next, I suggest several possible technical solutions to problems inherent in adopting a hierarchical paradigm.

Potential Modeling Strategies Reflecting the Hierarchical Structure of Landscapes

Lagrange Multipliers and Hierarchical Models

The scale-dependency of landscape structure implies that simple, linear extrapolation of model results obtained at one scale to other scales may not ensure that the necessary yields or amenities are obtained. Granted, the unique nature of each Forest demands that the application of FORPLAN be tailored to each location. However, a set of independent models and prescriptions may not combine to satisfy the national-level mandate of Congress put forth by the National Forest Management Act (Haimes 1977). Individual Forests face the same problem if optimization is done for individual analysis areas (e.g., Armel 1986). The optimal solution for a local management unit may be incompatible with the long-term goals of the Forest.

Similar problems occur in water resources management, and the hierarchical approach developed by Haimes (1977), and provided below in slightly modified form, seems appropriate for the extension of FORPLAN to a series of specific, interacting, management units. The key to this approach is the Lagrange multiplier, which helps link several small models hierarchically. It has the added benefit of accommodating nonlinear constraint equations, which perhaps should be considered as candidates for improvements to the current FORPLAN.

In essence, given an optimization problem with one decision variable, x, and the requirement to find

$$\min f(x),$$

with the constraint

$$g(x) = b,$$

the Lagrangian function, L, is defined as

$$L(x,\lambda) = f(x) + \lambda\,[g(x)-b]$$

where λ is a Lagrange multiplier. Specification of the stationary points of L yield two equations for the unknowns, x and λ:

$$\frac{dL}{dx} = \frac{df}{dx} + \lambda \frac{dg}{dx} = 0$$

$$\frac{dL}{d\lambda} = g - b = 0$$

Solving for the stationary points of the equations gives x* and λ which can be equated to min f(x) (Haimes 1977).

Application of this approach to landscapes requires a series of models for individual analysis areas (considered here to be precise geographic locations), with knowledge of the couplings between adjacent areas. Couplings might include the amount of energy, money, silt, water, and nutrients flowing from one analysis area to another. Then, as described by Haimes (1977), a hierarchy of Lagrange multipliers is developed to coordinate the analysis area models into a complete, optimized Forest system. Most important, the solution to such a model differs from the solution obtained by prorating a single Forest-wide model to smaller landscape units.

Nonlinear High Order Markov Models

Landscape dynamics are relevant to discussions of wildlife habitat and resource management. The appropriate habitat for a species shifts spatially through time as successional plant communities age, so a dynamic model would be helpful. Two aspects of landscape structure and dynamics suggest limitations of simple Markov models besides those shown by Shugart and Gilbert. These limitations may be reduced or eliminated. First, the "rules" applied to a landscape change through time because of Congressional mandates, public opinion, or Forest Service policy. Thus, the transition probabilities describing the likelihood of change from one cover type to another also change. Simple Markov models have constant transition probabilities, making them insensitive to changes in the rules controlling landscape change.

Second, neighboring patches may affect the transition probabilities of particular patches. For example, the staggered cutting method precludes the clearing of uncut timber if it is next to an existing clearcut. Damage from windthrow or fire may occur if a stand is next to a clearcut (Jerry Franklin, personal communication). Thus, a

"neighborhood" effect should be incorporated into Markov models. This is done using "conditional" transition matrices, where the probability of changing from one cover type to another is conditional, or depends, on the identity of the adjacent patch. Dr. Jean Hartman, at Harvard University, and I are developing such a landscape model incorporating both dynamic and conditional transition matrices. The greatest assets of Markov models are that few parameters and small amounts of data are required for simulation (compared with forest gap models). Thus, Markov models are a practicable way of reducing the number of variables required.

Wildlife Habitat, Bayesian Models, and Geographic Information Systems (GIS)

Managers often require knowledge of the precise location of animal populations or resources (Connelly 1986). Correlational studies of wildlife habitat (discussed by Shugart and Gilbert) may not provide such information, or it may be difficult to translate correlational relationships to maps. Bayesian classification provides a simple, alternative method for determining the most likely habitat locations for wildlife. Once developed, this technique could be readily applied to GIS-based versions of FORPLAN (Stephan 1986), and to FORPLAN coupled with a simulator of landscape dynamics, such as the Markov model described above. Precise predictions of wildlife habitat locations could be made using such versions of FORPLAN.

A Bayesian model requires maps of cover types and other landscape features such as slope and elevation. Each point on the landscape is described by a vector, **x**, containing the list of features present. Then, the "state" of wildlife populations, **w**, of each point on the landscape has a probability of occurring, conditional on the vector of landscape features. Examples of states include "wildlife species present" and "wildlife absent." According to Bayes' formula,

$$P(w_j|x) = \frac{p(x|w_j)\,P(w_j)}{p(x)}$$

where

$$p(x) = \sum_{j=1}^{n} p(x|w_j)\ P(w_j).$$

Here, $p(x|w_j)$ is the state-conditional probability density function for x, $P(w_j)$ is the *a priori* probability of state w_j, and $P(w_j|x)$ is the *a posteriori* probability of each state, given the set of landscape features present.

Neighborhood effects could be included in the vector of landscape features, if such effects were shown to be important. This model of wildlife habitat is easily applied using a GIS, and may be tuned to incorporate consequences of landscape structure. The sensitivity of this approach to the hierarchical structure of landscapes is not known, except that the model would probably provide less predictability if only very coarse resolution habitat information were available or if species sensitive to fine-scale habitat variation were of interest (MacArthur 1972).

In summary, recognition of complex spatial structure in landscapes requires special approaches to landscape modeling. Interactions between adjacent (and perhaps distant) patches precludes simple prorating of estimates over wide areas, or among locations with vastly different environments. Hierarchical models reflecting the scale-dependent structure of landscapes may be effective means of extrapolating from fine- to broad-scale predictions. In some applications, landscape dynamics may be simulated using enhanced Markov models, with the advantage of using many fewer parameters than are necessary in models based on gap dynamics. Twenty years ago few people would have envisioned the present capabilities of FORPLAN. There is every reason that future versions will be sensitive to the hierarchical structure of landscapes, and incorporate knowledge of the surrounding patches to predict changes within particular patches.

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An Evaluation of FORPLAN from an Operations Research Perspective

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Abstract.--FORPLAN is a computer system for developing linear programming models in support of National Forest planning. Technically, most deficiencies of LP can be overcome to correctly produce large-scale comprehensive models. However, the validity, reliability and usefulness of these models are in doubt because their opaqueness may exceed the analysts' ability to adequately interpret them for use in supporting politically-charged decisions. Better definition of the planning problem and closer tailoring of the analytical support is suggested.

Foreword

The following evaluation of FORPLAN is offered in an effort to explain some of the characteristics of National Forest planning and to make future improvements in the planning process. While at times critical, our comments are not directed at any region, forest or individual. To the contrary, we recognize the many fine accomplishments of a large cadre of men and women who worked tirelessly to develop, improve, and implement FORPLAN during the past few years. The many accomplishments attributable to FORPLAN are exclusively the result of their efforts. We also recognize that our evaluation is blessed with the added advantage of hindsight. Thus, the faults we find must be interpreted in this light. Finally, we acknowledge the direct and indirect help of the many people who have been involved in the development, refinement, maintenance, and implementation of FORPLAN.

Introduction

Perhaps the most difficult part of this paper will not be the evaluation of FORPLAN, but determining what is an "Operations Research" (O.R.) perspective. The president of the Operations Research Society of America, Stephen M. Pollock (1986), speaking to the diversity and broad charter of operations research recently said that, "... the great trinity of O.R.: problem solving (agenda setting, fixing goals and objectives); decision making (evaluating and choosing); and the necessary mathematical apparatus needed to achieve this (name your favorite technique, algorithm or heuristic) ... [leads to] ... the almost hubristic willingness of most operations researchers to attack normative or descriptive problems of the widest conceivable scope ..." Besides embracing the above listed tenets, an O.R. perspective also implies the adoption of a systems approach to problem solving. Coupled with a decision orientation and reliance on a quantitative assessment of alternatives, O.R. practitioners presume that a rational-comprehensive approach will lead to an acceptable solution to any given problem.

The past few years of forest planning have raised doubts about this last assumption. Nevertheless, with such a broad charter our evaluation could easily encompass almost everything in this symposium, and, we might add parenthetically, would be in keeping with the comprehensive nature of O.R. Further, we recognize that the analyses that natural resource economists (Krutilla and Fisher 1985) and systems ecologists (Shugart 1984) have described fall within this framework. Partly, this is because many scientific disciplines have embraced some of the tenets enumerated above, and partly it is because O.R. itself follows the scientific method. Because we do not wish to duplicate the evaluations from these points of view we must necessarily limit our evaluation somewhat.

Thus, our task is not to address the "problem" of National Forest management, or the "decisions" to be made by National Forest managers. While essential to a comprehensive evaluation, we will assume (perhaps incorrectly) that these evaluations will occur elsewhere. Instead, our objective is to evaluate the previously chosen "mathematical apparatus" -- FORPLAN: Versions 1 and 2 (Johnson 1986, Johnson et al. 1986). We will consider its technical basis and how well it has provided the information needed by decision makers. Simply put, we raise three questions: (1) Does FORPLAN work? (2) Is it the right technique and is it used correctly within the decision environment of National Forest planning?, and (3) Are the results useful? Simply put, the answers are: (1) Yes, but ..., (2) Possibly, but probably not, and (3) Occasionally.

We begin by describing the mathematical basis of FORPLAN, its inherent assumptions, and their implications. We note the "problem solving" and "decision making" difficulties that have been generated as a result of these implications, and we speculate about why FORPLAN evolved as it did and note some possible alternatives.

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Finally, we make some recommendations about addressing the "real problem," which heretofore has gone unanswered.

FORPLAN Is A Linear Programming Approach

FORPLAN (Versions 1 and 2) is a linear programming (LP) model. As such, it seeks to optimize a single linear objective function subject to a set of linear equality or inequality constraints. As described by Iverson and Alston (1986), FORPLAN is the outgrowth of a series of LP models developed and used by the Forest Service during the past 20-25 years. Without repeating this history, let it suffice to say that forest-level planning has undergone revolutionary changes during this time. Chief among these has been the legislated need for comprehensive and integrated multi-resource planning; public involvement in all phases of planning; the introduction of computerized planning models and data bases; and increased pressures on all the resources of the National Forest System.

FORPLAN is the mandated planning model in use on the National Forests and is an outgrowth of several earlier computerized planning systems: (1) RCS (Resource Capability System), (2) RAA (Resource Allocation Analysis), (3) Timber RAM (Timber Resource Allocation Method), (4) MUSYC (Multiple Use Sustained Yield Calculation Technique) (5) ADVENT (A Model for Program Budgeting), and (6) IRPM (Integrated Resource Planning Model).

All these LP models, plus others, influenced the development of FORPLAN Version 1, and subsequently, Version 2. A full accounting of this history is available in Iverson and Alston (1986), Johnson et al. (1986), Jones (1986), and Iverson (1986). For completeness, and to better understand FORPLAN and how it is used in forest-level planning, we begin our evaluation with a definition of LP along with its inherent assumptions and limitations.

What is Linear Programming?

Linear programming (LP) is a special case of the more general form of optimization techniques called mathematical programming. Mathematical programming is simply the representation of a problem in mathematical terms coupled with a formalized technique to find the optimal solution, usually without enumerating and examining all possible solutions. It is assumed that there is not a unique solution to the problem. Otherwise, there would be a mathematically straightforward -- but not necessarily easy -- way to solve the problem. Generally, a different solution technique (algorithm) is needed for different forms of mathematical expressions. Thus, there are many forms of mathematical programming and, as might be guessed, the difficulty of the algorithm increases with the complexity of the mathematical expression.

In an LP model, all the expressions have the form of linear equations or inequations and the accepted -- and until recently, the only -- algorithm for solving such problems has been the simplex. The general form of the LP problem may be expressed in matrix form as:

$$\text{Max } z = \mathbf{c'x},$$

subject to

$$\mathbf{A}\mathrm{x} \leq \mathrm{b},\ \mathrm{x} \geq \mathbf{0}$$

where:

A is an m by n matrix of constraint coefficients (n > m), where m is the number of constraints and n the number of decision variables.

b is a vector of m constraint levels,

c is a vector of n optimization criterion weights,

x is a vector of n decision variables,

z is the scalar value of the objective function,

0 is a vector of zeros.

An LP problem is likely to have an infinite number of infeasible solutions (do not satisfy the constraints) and, it is hoped, at least one and possibly an infinite number of feasible solutions (within the decision space). The simplex algorithm (Dantzig 1963) first finds a feasible solution, then makes systematic moves to other feasible solutions if it can improve the value of the objective function. If it cannot, it assumes it has found the optimal solution and stops. There may be other feasible solutions known as alternative optima which have the same optimal value of the objective function, but differ in decision space.

Solution time is a function of the number of decision variables and, more important, the number of constraints which define the decision space. Theoretically, the solution time for the simplex increases exponentially with problem size (combinations of n, m and non-zero constraint coefficients), but it rarely does so in practice. A radically different algorithm developed by Narendra Karmarkar of Bell Labs promises to do even better because its solution time appears to be polynomially, rather than exponentially, bounded. However, its performance has not been as spectacular as hoped and it has not been tested on a full array of LP problems (Hooker 1986). Whatever the outcome of the battle of the algorithms, very large problems are not likely to be solved by either method in a reasonable amount of time.

LP Assumptions and Limitations

Although the assumptions of LP are well known (e.g., see Dykstra 1984 or Kent 1980), the implications of these assumptions are not usually consciously considered by O.R. analysts or the general users of LP models. However, the interpretation of results and their implementation by on-the-ground managers depend heavily on these assumptions and their relationship to the "real world." Recently, Wilson (1986) reviewed the implications of these assumptions within the context of FORPLAN. We wish to pursue this topic in more detail.

First, because of its linearity assumption, LP is often criticized as being too simplistic to model many real world phenomena. "The world is not linear!" This is an oft heard battle cry, and is generally a valid observation. But, the implication of linearity that is most often challenged is

proportionally. This deficiency can be effectively overcome with proper formulation. For example, FORPLAN handles nonlinear timber yields with ease. Dealing with nonlinearities in the constraints and the objective function are admittedly more difficult. However, more complex algorithms can be used (e.g., quadratic programming), or the nonlinear constraints can be handled in a piece-wise linear fashion (Hrubes and Navon 1976). Such is the case with FORPLAN demand constraints.

However, the more insidious implications of linearity often are overlooked. These are the additivity and divisibility assumptions. Additivity means that any combination of feasible values for the decision variables produces a consequence which is the sum of the individual values. No interactions are permitted to cause variations from this total. The second implication -- divisibility -- allows a decision variable to take on a continuous range of values. In many LP models, however, integer-valued decision variables are required (e.g., FORPLAN Version 2 with coordinated allocation choices). To permit a noninteger value implies infeasibility in the real world, making such a solution difficult to implement.

LP does not allow interactions and it does not guarantee integer solutions. More often than not, these are important considerations in forest-wide modeling as found on the National Forests. Careful formulation of the model and cautious interpretation of the solutions may allow one to avoid incorrect results without resorting to more complex and costly alternatives such as nonlinear and mixed integer programming. However, this is doubtful with large, complex models such as FORPLAN, especially Version 2 with coordinated allocation choices.

Another commonly cited criticism of LP is that it is deterministic. This is because probability functions, which are often nonlinear, are impossible to incorporate into LP models. Hence, all coefficients in an LP model are assumed to be known with certainty. If we attempt to incorporate uncertainty into an LP model, both model size and solution time increase dramatically. Thus, probabilistic elements are usually omitted from LP models.

A final weakness of LP is that it explicitly assumes there is a single decision criterion to be optimized and implicitly assumes there is a single decision maker. Neither of these generally hold for the National Forests in practice or for public decision making in general. There are many algorithms, procedures, and alternative modeling techniques to overcome these deficiencies. National Forest planning has used few of these, and FORPLAN even fewer.

As serious as these implications are, they are not a *raison d'etre* for dismissing LP out of hand. Invariably, no approach will produce a perfect model of the real world, because all models are abstractions which necessarily are simplifications of reality. However, some models perform better than others, given: first, the objectives of the modeler; second, the modeler's operational constraints; and, last, the form of the situation being modeled.

The greatest danger, then, with using LP, or any modeling technique, is not that it doesn't work perfectly, but that it is working less perfectly than the modeler (or client) thinks it is. Having a million-dollar LP model that gives results no better than could be worked out on the back of an envelope is not only a glorious waste of money, it also may be horribly misleading about the confidence that should be placed in the results. Is that the case with FORPLAN? It could be. Let us look more specifically at its assumptions, structure and characteristics and compare it to other classes of LP models.

FORPLAN as an LP: Does it Work?

From the previous discussion, we can see that LP can be deceptively simple. But the assumptions and the potential solution difficulties can not only lead to misinterpretations (as will be discussed later); they can also prevent it from working at all. It is well known that in the early days some FORPLAN models were never solved because of their size. Some were probably too large to even fit in the machine. See, for example, Barber's (1986) excellent discussion on large FORPLAN models, and the critique of Version 1 by Iverson and Alston (1986).

Given that the Forest Service was using one of the largest mainframe computers and a state-of-the-art solution code, this implies that FORPLAN models were exceeding the limits of experience in LP (Kent et al. 1986). Furthermore, FORPLAN models are generally of the most complex form of LP, known as "blending problems." Such models typically have several choices for their size and many non-zero constraint coefficients. These severely tax any solution algorithm by increasing the computations necessary to invert the matrix (an integral part of the simplex algorithm) and by requiring more iterations to find an optimum solution, which may be only marginally different from a solution arrived at thousands of iterations earlier.

To be more specific, FORPLAN Version 1, Model II forms typically have very sparse matrices (less than 1% non-zero constraint coefficients) because of the many Model II transfer rows. The Functional Mathematical Programming System (FMPS) SPRINT algorithm (Sperry Univac 1984) is designed to solve such problems very efficiently and generally does so. However, few forests use Model II except those in Regions 5, 8 and 9, and at least one forest in Region 8 exceeded FMPS's unadvertised row limit of 8,192 when it generated its matrix. The alternative Model I form was much smaller but also denser, about 8-10%. Most Model I matrices are not so dense but are still likely to be an order of magnitude denser than a nominally equivalent Model II. FORPLAN Version 2 has the ability to produce more complex models than Version 1, and thus has the potential to produce even denser matrices. We have seen them with as many as 20% non-zero constraint coefficients. This seldom occurs, however, because most Version 2 models use coordinated allocation which introduces many sparse transfer rows with a corresponding overall reduction in density.

The alternative FMPS solution algorithm, OPTIMIZE, was considerably less efficient in solving FORPLAN models. However, it was believed to produce more accurate marginal information than SPRINT, and better bases for post-optimal analyses. However, little use was made of FMPS post-optimal techniques because the time and funds that would have been necessary to perform such analyses

were already committed to meeting other requirements. That limited experience suggested that such procedures were not very well documented and proved to be inefficient, the reasons for which are uncertain.

Several actions were taken by the FORPLAN developers, the Fort Collins support group and Sperry to overcome problems caused by these massive and dense matrices and to reduce solution time and cost. Kent et al. (1986) have reported on the considerable progress that has been made. With a larger, more powerful machine already on the floor and new operating systems and LP packages in the pipeline, additional improvements are also assured. But in the past it has seemed that a bigger model was just waiting to be generated as soon as the existing limits on model size or solution time were relaxed. This, too, is likely to continue albeit at a slower pace until the next cycle of planning hits. While most FORPLAN models have been satisfactorily solved -- although not always inexpensively -- we still must conclude that FORPLAN is taxing the LP state-of-the-art. To us this would seem to be an incentive to consider alternative cures of the disease rather than applying more Bandaids.[2] Thus, our answer to the question, "Does it work?" is "Yes, but . . .."

FORPLAN as a Model: Is it the Right Technique and Correctly Used?

If we conclude that FORPLAN works, then we might consider the question, "Is it the right technique and is it correctly used within the decision environment of National Forest planning?" Based on our previous discussion about the linearity and certainty assumptions we could easily answer, "No way!" However, we also could say the same thing about almost any natural resource model when compared with reality. From this standpoint then, a negative answer is too flip a response.

An astute and clever analyst can often use a crude and seemingly inappropriate model to discover some important information about a situation. Some also suggest that the "black box" approach allowed a clever analyst to produce any result that was determined "*a priori*" to be desirable. However, a not-so-perceptive analyst may use an exceedingly complex model to innocently arrive at incorrect findings. Any other combination of these types of analyst, model and results could also occur. FORPLAN produced some of all; probably more of the gross errors than of the brilliant insights. Much of what it produced was somewhere in between.

Analysts in Region 8 and elsewhere were repeatedly challenged to explain why FORPLAN produced the results it did. They were not expected to predict the results, but once they were available, they should have known where they came from. To do this, they generally had to make their models less comprehensive than had been originally envisioned.

[2]The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

It may be asked that if the results were so logical that they were readily explainable, was such a complex model necessary? Possibly not, but we can find examples of explainable, yet, unpredictable results that may not have been detected by a cruder model. For example, most FORPLAN models will produce the following results unless they have been otherwise constrained: they combine early profit taking with a maximum delay in costs (partially related to the allowable cut effect) which leads to markedly increasing budgets over time; they delay timber harvests for one to five periods; they assign recently cutover timberland to minimum level management; and they provide for a declining timber yield in the n + 1st period (or planning horizon plus one) if the solution is projected beyond the end of the planning horizon. These results often violate policy or law but may not be illogical given the model assumptions about resources and economics. If the model cannot avoid such results without arbitrary constraints, then something is either wrong with the model or the policies that are being violated.

A closer examination of the timber harvest delay situation illustrates the models' ability to challenge questionable assumptions. Harvest delays generally occurred because the timber price trend was assumed to be nearly as large or larger than the discount rate. In Region 8 the models' reluctance to harvest softwood in the first decade was detected early on, explained away as an historical trend that was not current and was unlikely to manifest itself in the future, and then it was by-passed with constraints. Under this argument it should have been changed, not by-passed, or at least tested with other assumptions.

In the West, this damaging assumption was even worse, because it tended to hold timber for five decades, and yet, it went undetected for years because of the complex way stumpage was calculated by the model. Eventually it was discovered and remedied with new price and trend assumptions based on more recent market information.

One wonders how many other invalid assumptions, miscalculations, or simple data entry errors lurk in these massive models. As Barber (1986) notes, large models are virtually opaque to their users and must be accepted on faith. This is a dangerous situation!

It might be instructive at this point to separate two related, yet, slightly separate aspects of the question being addressed. First, as discussed above, the "black box" nature of FORPLAN allows for data errors and hidden assumptions to go undetected. This can lead to misleading results with dubious consequences. But, apart from this, the violation of the assumptions inherent in LP also must be mentioned. FORPLAN solutions have been generated for problems which do not exist on the ground. For example, the violation of the divisibility assumption implies that many solutions require clever "interpretation," or new solutions need to be found before on-the-ground implementation can be assured. Further, the assumption of certainty is almost certainly violated in every FORPLAN run. At a minimum, sensitivity analysis is required to gauge the significance of this violation.

We suspect that these additional analyses were probably not done usually because of time and cost considerations. More than likely, noninteger solutions were "rounded off"

for practical reasons. Whether such rounded solutions are even feasible, let alone optimal, seems to be a seldom-asked question. Other such violations could be cited; but our point should be clear.

Apart from these deficiencies of model solutions we must raise another important issue. Before we can answer the question of whether FORPLAN was the right model, we must determine if LP itself or the need to be comprehensive is the real concern. We suspect that much of the blame must be placed on this latter need. By placing so much emphasis on the need for comprehensive, multi-resource integrated planning, O.R. analysts working for the Forest Service were quick to conclude that only the development of a large scale model capable of handling forest-level planning over a 15-30 decade planning horizon involving a multiplicity of goods and services would satisfy legislated mandates as perceived by higher-level management. Given this mandate, it is no wonder that LP became their chosen tool.

The analysts were given the opportunity to show the rest of the organization that "technology" would be their salvation. As previously discussed, in 1979 it is likely that the young technocrats making these decisions were largely unaware of the difficulties which lay ahead in solving the large LP problems which would result from this comprehensive approach. With hindsight, had the analysts resisted the temptation to design a single large model capable of simultaneously making land allocation and scheduling decisions, we might not have been led to this ex post facto justification of FORPLAN.

Following the agency's drive to be comprehensive, the analysts took the straightforward approach of including everything they could in one giant LP model. We wonder if a multi-stage approach might not have been a more logical and understandable approach given what we now know. We recognize that this could have been accomplished using FORPLAN as shown by Mitchell (1986); but the procedural directions tended to discourage it. While such an approach may not guarantee optimality in a model sense, it may well produce more understandable results which can be defended and implemented in the real world. This trade-off between model comprehensiveness and understandability, especially when dealing with public forest management issues (Allen and Gould 1986), needs to be evaluated before the next round of forest planning begins.

Thus, our answer to the question, "Is FORPLAN right?" is, "Possibly, but probably not." If one cannot logically explain the results outside the model, then it is doubtful that they are valid. If they can be explained, it is still no guarantee that there may be transparent formulation or data errors that are producing a reasonable but wrong answer. The best we can hope for is that by completely understanding the assumptions of LP, the formulation of the FORPLAN model, and the interpretation of the solution, we can then be reasonably confident that it is correct. We suspect that this occurred on few forest planning teams.

FORPLAN as a Planning Tool: Are the Results Useful?

You may have noted that the arguments in the previous section seemed to favor a negative response to the question posed, and yet, we arrived at a mildly positive answer. An obvious reason is that we could not have logically asked the final question if we had concluded FORPLAN to be invalid. At a minimum, we believe that FORPLAN was used as an accounting tool to accumulate the numbers that were required to be present in the planning documents. We accept that and also recognize that some simpler and more understandable approach could have been used if that had been its only purpose.

We are much more concerned with whether FORPLAN was successful in developing and supporting valid forest planning decisions that would not otherwise have occurred. From our discussions with forest analysts, planners, and supervisors, we conclude that there were some very important insights gained from FORPLAN analyses that contributed to novel and defensible recommendations for National Forest management. You will note that we did not say that they got their answers (decisions) from FORPLAN. The distinction between insights and answers from analytical models is very important and must not be overlooked (Geoffrion 1976, Brill 1979, Iverson and Alston 1986).

The forest planning procedure which required benchmark runs, a variety of diverse alternatives, and constraint analysis promoted this notion that FORPLAN was seeking information, not answers. It also helped to overcome some of the deficiencies of the approach in the area of multiple objectives and multiple decision makers. However, the prescribed minimum standards should have been merely the basis for more rigorous sensitivity analysis to gain even more confidence in the model and thus, insights into the problem. Unfortunately, the models were generally too large, the time too short, the computing budget too small, and the analytical skills too limited to allow much of this to occur except perhaps in the development of the preferred alternative.

Instead, there appeared to have been no clear understanding of the relationship between analysis and decision making. Analysts thought they should be making decisions and often did so, sometimes without realizing it. For their part, the real decision makers (forest supervisors) were more likely to reject analysis as being irrelevant, incorrect or simply threatening to their existence. Failure to do real analysis or failure to recognize the distinction between insights and answers probably led to many of the unsupportable decisions based on invalid FORPLAN results.

There was a tremendous amount of FORPLAN analysis, both good and bad, that was simply not used in making forest planning decisions, sometimes for very good reasons. It is unlikely that the amount of valid results that was used to support good recommendations exceeds the amount of invalid results that was used to support bad recommendations. Plus, there was a tremendous amount of analysis that was just plain wasted!

It would not be hard to accept the conclusion of many that the costs of FORPLAN have far outweighed the benefits. However, we are not yet ready to completely

discount the future benefits to natural resources management that may be attributed to the experiences gained and the knowledge produced in this massive attempt to model our National Forests (Field 1984). Concerning valid FORPLAN results supporting defensible forest plans, we conclude that this occasionally occurred, but nowhere nearly as often as was envisioned when the planning procedures and analytical techniques were adopted.

Thus, our evaluation of FORPLAN as the mathematical apparatus for forest planning points neither to an unqualified success nor to a dismal failure. We would probably give it a grade of C-. It will be instructive to examine more closely how FORPLAN got to this point, and to consider past, present and future alternatives for the analytical support of forest planning.

Why Is FORPLAN An LP?

Given the difficulties with LP itself and its later use to model forest-level planning, as noted in the last few sections, why were these problems not recognized ahead of time and a different analytical system selected? How and why did we get into the position we are now with FORPLAN? Could it have been avoided? Were there alternative methods then, or are there now? How might forest planning be differently analyzed in the future to improve support for National Forest decision making? These questions are addressed in the following sections.

FORPLAN: An Example of the "Peter Principle?"

Iverson and Alston (1986) and others at this symposium have clearly outlined the "genesis of FORPLAN." There is little doubt about its lineage, and we do not wish to repeat it any more than we have already done. However, it seems to us that the existing recitations of FORPLAN's history have not sufficiently clarified the motivations for its being. Without such a clear understanding, we may be doomed to repeat history rather than learn from it.

The "choice of FORPLAN" seems to have revolved around four conditions as they were perceived by the Forest Service in 1979. These were:

1. The agency believed that an optimization technique was necessary to satisfy the requirements of the NFMA regulations.

2. The legislated requirement for a comprehensive and systematic evaluation of all the goods and services produced by a National Forest to maximize net public benefits led the agency to the inescapable conclusion that a large scale, forest-wide, multi-resource land allocation and scheduling model was necessary.

3. The National Forests -- and forestry -- lacked the skills necessary to leave the choice and implementation of this technique to the forest supervisors, and even were it possible, the agency would not relinquish control over the process.

4. LP was nearing the peak of its 20-year ascendancy as the accepted analytical technique for any forestry problems involving allocation and scheduling, especially timber harvest scheduling. Conceptually at least, it had already been applied to the comprehensive job of "forest management."

The Forest Service was not alone in its infatuation with LP, nor was forestry alone in its infatuation with optimization. But while much of the rest of our society was beginning to show some skepticism and disillusionment with the "Whiz Kids" of the McNamara era, the conservative forestry profession was just discovering that perhaps they could realize Pinchot's mathematically impossible dream. Meanwhile, examples were beginning to accumulate that showed the failure of many large-scale, multi-resource models (Mar 1974 and Lee 1973).

The Forest Service combined forestry's conservative nature with its own paramilitary professionalism to see the job through, and embarked on an analytical task heretofore unrivaled in the annals of operations research. This was to build a detailed mathematical model of each of the 154 National Forests and solve it to maximize the net benefits to society. Choosing LP as the optimization technique was the only logical choice that could be implemented by its personnel. Applying it "brute force" to the joint problems of allocation and scheduling was perhaps a major mistake, although it may not have been avoidable given the agency's mind-set in 1979. At any rate, FORPLAN may well have raised LP to its level of incompetence.

What Were the Alternatives in 1979?

Considering the analytical techniques that were available in 1979, there was another that rivaled LP's domination of the field (Martin and Sendak 1973, Field 1976, Elbourn 1977, Bare 1971). This approach was simulation, a very early entry into the harvest scheduling field (Sassaman et al. 1972) that was soon dominated by LP (Johnson and Schuerman 1977). Simulation continued to be heavily used in non-optimizing forestry applications, but has yet to make much headway against LP in harvest scheduling, for reasons outlined by Johnson and Tedder (1983).

There have been some improvements in both approaches by incorporating certain capabilities of the other; but Johnson and Tedder conclude that "the search continues for a technique that integrates the best features of both approaches: many inventory categories along with many harvest constraints using a search procedure that guarantees attainment of the optimal solution." Whether this idyllic method will emerge for harvest scheduling says nothing about its possibilities for the much more complex job of comprehensive forest planning. Furthermore, the decade of the 1970's brought much doubt about the viability of large scale simulation models for aiding decision makers faced with complex environmental and land use issues (Mar 1974). There was little chance that simulation could do the job in 1979.

Other optimization techniques had been applied to forestry problems. Some were completely different mathematical programming techniques, such as dynamic programming (Hool 1966), control theory (Anderson 1976), inventory theory (Pelz 1977), integer programming (Bare and Norman 1969), and quadratic programming (Romesburg 1974).

There were also a few variations of LP, most notably attempts to address decision making under uncertainty with probabilistic LP (Thompson and Haynes 1971). Attempts to overcome the problems of LP model size by decomposition techniques were reported as early as 1967 by Liittschwager and Tcheng. Almost without exception, these reports and the similar efforts which followed them were experimental in nature and never saw even limited application, at least in the arena of optimal harvest scheduling which fathered FORPLAN. Another variation of LP, network analysis, was seeing considerable application in transportation planning and its even simpler forms of PERT and CPM were being routinely applied to project planning problems.

Other analytical approaches applied to forestry problems included input-output analysis, decision theory, nonlinear programming and separable programming. None seemed able to address the scale of problems found in forest planning or the conditions for optimality. Possible contributions to problem definition, to generating planning alternatives, and for refining planning procedures appear to have been overlooked.

During the 1970s, the area of multiple criteria optimization was being rapidly developed. Forestry became enamored with goal programming (GP) from the work of Dave Field (1973). Its application to land management planning seemed to be particularly attractive (Bell 1976). While certain problems were noted with its application and interpretation (Bell 1975 and Dyer et al. 1979), a GP system was installed at Fort Collins for the use of Forest Service planners (Bottoms 1976).

Largely because of a complementary LP and GP procedure developed by Field et al. (1980) that appeared to overcome these problems, GP options were incorporated in the FORPLAN system. These options were seldom used except by several forests in Region 8 to develop alternatives in the face of conflicting objectives. One other multiple criteria approach, multiple objective linear programming (MOLP), had been applied to a forestry problem (Steuer and Schuler 1978) with limited success on a small scale. Most of the other approaches which were gaining wide acceptance in water resources planning (Cohon and Marks 1975) have yet to receive much attention from forestry.

The modeling technique which would seem to have the most useful application to the problem addressed by FORPLAN was some form of decomposition. Most of the work after Liittschwager and Tcheng (1967) involved specialized combinations of LP, DP, and Dantzig-Wolf decomposition (Nazareth 1980, Williams 1976, and de Kluyver et al. 1980). These approaches, like the other optimizing procedures discussed above, would have been difficult, if not impossible, to implement under the Forest Service's conditions for modeling.

However, Dress (1975) had proposed a more generalized, two-stage approach to forest planning which did not win the FORPLAN sweepstakes (Jones 1986), but was sanctioned for use with FORPLAN in Region 8. A system to perform the first stage, steady-state analysis (Steady-State Analysis Model, SSAM) was developed (Field et al. 1981) but its linkage to FORPLAN was never established. This and the exhaustive efforts necessary to develop the required FORPLAN models prevented SSAM from ever being applied. At the same time, there was a concerted effort by the FORPLAN developers to head off any efforts to challenge FORPLAN's role as the simultaneous allocation and scheduling model (Crim 1982). As a result, the only innovative, multi-stage forest model that has been developed to date is Tom Mitchell's (1986) Shoshone model. This approach appears to have sufficient merit to warrant critical evaluation (Connelly 1986).

Considering the private industrial forestry sector before 1979, there were even fewer reports of successful applications of modeling systems other than LP and simulation. Comprehensive and integrated efforts the size of FORPLAN had not yet been attempted in industry and most that would be tried in the next 5 years would fail. Thus, in 1979, the decision to use an LP system for forest planning was principally because of the lack of any tested and experienced approach other than the harvest scheduling models of industry and the Forest Service, as postulated by Ware and Clutter (1971) and Navon (1971).

There was apparently no attempt to consider other modeling systems outside forestry or even in the broader field of planning. Given that such systems would have to be tested and proven in forestry, and that Forest Service personnel would have to be trained in their use before they could be applied, this lack of consideration may be justified. The observation that with FORPLAN the Forest Service was "trying to build a bicycle and ride it at the same time," would have been even more appropriate had the agency selected an approach with which the profession had no experience.

Forest Service analysts were justified in selecting LP as their prime "mathematical apparatus" to drive the forest planning process. However, as already stated, the major flaw rested with the decision and (yes) the desire to satisfy the need for comprehensive analysis by building and solving a single, large scale LP model with thousands of rows and tens of thousands of columns. Apparently, insufficient thought was given to two fundamental questions: (1) Was the model to be used to guide strategic, tactical, or operational planning?, and (2) How relevant would model results be to on-the-ground managers and how easy would it be to explain model outputs?

As a result of this, we have today the FORPLAN system which produces models which:

1. Are too large, too poorly understood, and too costly in terms of set-up time, solution time and user skills to have been more than of limited value to the present planning efforts and little or no value to support decisions in the future.

2. Do not adequately address the different but linked problems of forest planning: strategic (allocation), tactical (scheduling), and operational (implementation).

3. Do not recognize or comfortably fit the real process of making decisions on the National Forests which is more political than analytical.

What advances in analytical methods have occurred since 1979 that may help overcome these deficiencies?

Where Are the Alternatives Now?

It would appear that mathematical programming has become deeply embedded in the tool kit of the natural resources analyst. Witness a text book devoted entirely to the subject recently published by Dykstra (1984). Meanwhile, experimental work has continued in at least as many modeling areas as were identified in the previous section. Among these are methods to reduce large models (Barber 1985 and Navon et al. 1986), new decomposition techniques (Berck and Bible 1984 and Hoganson and Rose 1984), additional applications of multiple criteria optimization (Allen 1986, Bare and Mendoza 1987, and Arp and Lavigne 1982), and applications of generalized network analysis to natural resources management (Glover et al. 1984). Holling et al. (1986) have successfully shown a blend of simulation and optimization where a simplified Markov-process optimizer serves as the "brain" for a large-scale ecologic simulation model. Hoganson and Rose (1984) take the opposite approach and solve a large-scale LP model by simulation techniques.

Among the new approaches that have been introduced is the use of heuristics with mathematical programming (Navon and Weintraub 1986). Swindel (1984) suggested game theory for some aspects of forest management planning and McLean (1983) recommends a systems approach called positional analysis. This is just a sample of the considerable work that has been done in the last 5 - 10 years. Four large compilations of this work in forestry are Harrison and de Kluyver (1984), Bare et al. (1984), Kallio et al. (1986), and Field and Dress (1986). There are also tremendous resources outside forestry; for example, a compilation of papers on optimization models for strategic planning by Naylor and Thomas (1984).

There also have been at least three reports of successful applications of LP to integrated industrial forestry problems. The first is a non-partitioned model described by Barros and Weintraub (1982). Notably, it is a very small model (1000 rows by 2500 columns) compared with most FORPLAN models. Most other integrated industry models have failed because of problems similar to those encountered in National Forest planning: size, lack of data, uncertainty, and unmodeled political realities within the organization.

Hay and Dahl (1984) have apparently overcome these problems with a successful modeling of strategic and tactical planning in Weyerhauser's southern operations. They use LP models for each phase; but they do not appear to be explicitly linked except by common data and assumptions. Both are small, the strategic model being the largest with about 900 rows and 7000 columns. It contains aggregated versions of the smaller tactical models which may have as many as 350 rows and 700 columns.

The final report by Weintraub et al. (1986) describes an application similar to Hay and Dahl. However, they give considerably more attention to validating the linkage between the strategic and tactical models and use mixed integer programming techniques to solve the strategic model. This approach was introduced by Nautiyal et al. (1975) but has seen little use in forestry, despite its logical application to strategic decisions of an "all or none" nature. Weintraub et al. show the applicability of a hierarchical approach to forest planning and prove it to be mathematically tractable. Hof and Pickens (1986) recently tested a similar application to public resources planning with mixed, but potentially promising, results.

The lesson from Weintraub et al., Barros and Weintraub, Hay and Dahl, Hof and Pickens, and Mitchell's Shoshone model seems to be that if one recognizes the hierarchical nature of planning and uses separate models, tailored to each specific phase of planning, there is more chance for successful support of management decisions. A considerably more rigorous and risky alternative would be to adapt some large-scale systems approach involving optimization, simulation, heuristics, and formal decomposition procedures. Such an approach is unlikely ever to be within the capabilities of the Forest Service to develop, implement and manage.

Conclusions and Recommendations

The Forest Service choice of an analytical model to aid National Forest planning, FORPLAN, was logically supported by the limited availability of optimization techniques that had been applied to forestry; by the analytical skills available to the agency; and by the limited time necessary to complete the plans. Technically, the LP approach would have been acceptable had it been properly applied (i.e., recognizing the hierarchical nature of planning and its relationship to decision making) with a complete understanding of its limitations and their implications. This was, unfortunately, seldom the case. As much to blame for this failure may be a misinterpretation of the planning problem that the agency faced.

It is sometimes convenient to blame a plane crash on mechanical failure when it was pilot error. Let us be careful not to blame FORPLAN for all the evils of forest planning. FORPLAN was the product, not the producer, of comprehensive forest planning. Irland (1985) has noted that "comprehensiveness is a trap ... comprehensive planning fails to sort the strategic from the trivial, wastes resources on secondary concerns, paralyzes the will in the face of complexity, and bogs down in empirical debates for lack of direction." Allen and Gould (1986) further detail these criticisms in irrefutable fashion. As discussed above, we too believe this to be the major flaw in the development of most FORPLAN models.

Before any attempt is made to extend, improve, correct, or change the existing analytical apparatus, the relationship between the hierarchical nature of planning and decision making in the Forest Service must be completely and satisfactorily resolved. As previously noted, this issue is beyond the scope of this paper and this symposium; but it

must be addressed before any rational selection of tools to support it may be made.

A team of decision makers and planners should study the agency's accomplishments and failures in planning, expected futures for the agency, and the use and success of planning in other organizations; and propose a new framework for planning in the Forest Service. It is important that this team is aware of changing philosophies in planning as noted by Gluck (1985) to avoid hopping on the bandwagon just as the horses are being unhitched. Equally important is to be aware of the dangers of poor implementation (Gray 1986). Recognizing that planning is the continuous technique of adapting the organization to its environment (Michael 1980), every effort should be made to integrate planning with management (Meising 1984).

Some knowledge of the capabilities of planning tools will be useful in this self-examination; but it must not be allowed "to drive the solution" as it may have from 1976 to 1979. Many believe the need for optimization and the benefits of LP were greatly oversold. They are probably correct. Forest planning may have been a nail that could have been very effectively driven with a hammer. But we had learned to use a fancier tool, a screwdriver, so we filed a slot in the nailhead. Try driving a slotted nail with a screwdriver - it will not work. Maybe that is what happened with FORPLAN and forest planning.

However, it is likely that current or near future capabilities in the storage, retrieval and manipulation of information will dramatically alter planning and decision making. Examples are the ever-increasing capabilities of micro systems available to remote users, low-cost geographic information systems, practical systems involving artificial intelligence, and the underexploited power of parallel processing. These implications must not be ignored for they are certain to change, if not eliminate, the role of many staff functions and middle managers.

Once planning is defined, a task force of decision makers, planners and analysts should be appointed to completely specify the analytical support necessary. Part of this specification must be the level of administrative support that will be assigned to the planning function. This includes authorizations for hardware, software, maintenance, analytical skills of the users, and managerial time to work closely with the planners and analysts. These specifications, once approved by agency leadership, should be issued in the form of a "Request for Proposal" of a planning support system for the Forest Service. Proposals should be carefully examined for compliance with the specifications, proven technology and expected reliability. The best, but not necessarily lowest, bid system should be purchased and installed.

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Evaluation of FORPLAN from an Operations Research Perspective: Discussant's Comments

Dennis P. Dykstra[1]

The paper by Bare and Field (1987) provides a useful overview of the technical considerations relevant to an evaluation of any large-scale, applied programming model. I will not comment on their opinions about the motivations that led to the adoption of FORPLAN because such speculations do not seem to me to be particularly relevant to the evaluation of FORPLAN as a technical entity. For the most part their discussion of the technical aspects of planning with FORPLAN agrees largely with my own preconceptions, so my remarks are confined to a few points that I think require additional clarification. These points fall into three categories: data errors, the definition of analysis areas, and hierarchical, or multi-level, planning.

Data Errors

As Bare and Field have stated, no large-scale programming system is ever likely to be completely free of logical and programming errors. The important thing is that the code should be free of errors that might have a significant impact on the problems being solved. I must admit that my experience with FORPLAN has only been second-hand, and, therefore, I am more than happy to accept the judgment of Bare and Field that, with a few possible exceptions, FORPLAN seems to be free of significant errors of this type.

However, broadly as they have interpreted their "operations research perspective," Bare and Field have little to say about **data** errors, which I consider to be a potentially much more devastating problem than programming and logical errors.

Data errors tend to be serious because of the likelihood that they will escape detection. In a model such as FORPLAN it is reasonably likely that logical and programming errors will be caught at some stage, especially because there is a large community of users, unless the errors themselves are sufficiently innocuous that they don't matter very much.

The kind of data errors that are most insidious are **not** data-entry errors, which can usually be discovered by carefully auditing data files. Rather, the most serious data errors are those of **measurement** and **classification.** Measurement errors are the most fundamental, and affect all resource decisions. There is little that FORPLAN analysts can do about such errors, because the analysts are not the ones charged with making the measurements. For certain kinds of resources, such as timber, the Forest Service has developed reasonably good procedures for avoiding such errors and we can probably be confident that most existing measurement errors related to timber resources are at the very least unbiased.

For non-timber resources, though, the situation is not so clear. Conventions relating to the assessment of recreation potential, aesthetic resources, soil erodibility, wildlife habitat, water yield potential, range condition, and other non-timber resources have not been clearly established. These assessments are subject to large measurement errors, if we are even willing to refer to the kinds of judgments commonly used in making these assessments as "measurements." Although work underway at the Rocky Mountain Forest and Range Experiment Station's Multiresource Inventory Project should help define appropriate measurement procedures for non-timber resources, the current round of NFMA planning lacks any such comprehensive guidelines. As a result, the data used in making FORPLAN runs is inevitably flawed because of substantial (and unknown) differences in the variance associated with estimated resource levels (and projections over time) for timber and non-timber resources. Because the planning effort is specifically directed at multiresource analysis, this appears to me to be a very important difficulty. It is **not** inherently a FORPLAN problem; any multiresource planning method that attempts to do planning at the level of detail prescribed for the FORPLAN analyses would face the same difficulty.

Classification errors, as contrasted with measurement errors, may result directly from the FORPLAN analysis itself. The FORPLAN analysis requires that certain decisions be taken by the planning team, and these decisions will have a profound effect on the results. One such decision is the identification of analysis areas.

Analysis Area Definition

Recently, together with some of my colleagues at Northern Arizona University, I've been reviewing the plans of several of the National Forests in Arizona. One thing we've noticed is that different forests have used completely different approaches, based on an entirely different set of assumptions, in the definition of analysis areas. On one Arizona national forest, for instance, the planning team made a considerable effort to recognize the spatial distribution of resources as one element in the definition of analysis areas. For the most part, their analysis areas are contiguous because the planning team felt that the plan should reflect the way the forest is managed. The planning team of another Arizona national forest, in contrast, used a more conventional forest strata approach in identifying analysis areas, so that a single analysis area is made up of small pieces scattered all over the forest. I suspect that this is typical of the way most national forests have identified analysis areas.

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The reason I believe this point is important is that it will influence, perhaps markedly, the results of the FORPLAN runs, particularly the calculation of present net worth. If you require that analysis areas be contiguous, you construct an implied constraint that will restrict the feasible region and possibly reduce the calculated present value of certain or all the alternatives being tested. This fact has often been given as a reason for permitting analysis areas to be non-contiguous. That's well enough if you can manage the forest in small, scattered pieces, but if operating plans concentrate on larger, contiguous blocks, then the implied constraints ought to be in place. Otherwise FORPLAN, or any other planning method, will overestimate net present value.

A final point about the definition of analysis areas, based on research in multiresource management we have underway at Northern Arizona University, is that different resources may require different definitions of analysis areas. Wildlife, for instance, do not respect the vegetative boundaries that have commonly been used in defining analysis areas for FORPLAN runs. Proper consideration of overlapping analysis areas for different resources will require implementation of overlay methods similar to those used in geographic information systems.

Hierarchical (Multi-Level) Planning

From discussions I've had with several forest planners, my impression is that one of the worst features of the current round of NFMA planning is that many of these planners and their colleagues on the planning teams have been "burned out" by the experience. I suspect that this is largely because of the level of detail required in the planning effort. This requirement has led to the necessity to develop and process vast quantities of data, and has resulted in FORPLAN models with an enormous appetite for computer time and disk space.

I agree with the assessment of Bare and Field that FORPLAN, as used by most national forests, does not adequately address the different but related problems of forest planning: strategic planning (allocation), tactical planning (scheduling), and operational planning (implementation). It seems to me, however, that their recommendation does not go far enough. I believe rather strongly that to support its future planning efforts, the Forest Service should adopt a planning system that specifically recognizes these distinct but interrelated levels of planning. Strategic planning ought to be done at a regional or national level, and it should use an appropriate level of resolution, recognizing that the kind of detail needed to manage individual forests is unnecessary for strategic decisionmaking, and merely gets in the way. Tactical planning ought to be done at the forest level, with a higher level of resolution, and operational planning at the district level. This final level of planning should be very site-specific and should rigorously maintain spatial integrity. It is at this level that planning and management should be fully integrated, and not at the higher levels.

Hierarchical planning of this sort is similar to the multi-level optimization concept being developed by Tom Hoekstra, John Hof, and their colleagues in the Land and Resource Planning Project at the Rocky Mountain Forest and Range Experiment Station. This type of approach to forest planning and multiresource management seems to me to be far superior to the single-level approach typified by most current applications of FORPLAN.

Literature Cited

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An Evaluation of FORPLAN from an Operations Research Perspective:Discussion Paper

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Abstract.--A framework for evaluating computerized systems for public land management planning is used to review and extend Bare and Field's analysis. The linear programming (LP) system FORPLAN is a powerful and appropriate tool for public land management planning. However, thorough validation of the FORPLAN models and extensive sensitivity analysis of the LP solutions are essential to determine the reliability of the computerized analysis. Adequate and cost-effective sensitivity analysis and validation require FORPLAN LP models which are smaller and simpler than those typically used in the current cycle of planning. A hierarchical planning strategy for using FORPLAN, which is consistent with simpler and smaller FORPLAN models, is sketched and evaluated.

Bare and Field observe that in 1979, when FORPLAN was chosen as the system for elaborating land management plans for all National Forests, no other system met the Forest Service needs:

- to satisfy the optimization requirements of the National Forest Management Act;
- to control and to promote uniformity in planning among the National Forests;
- to use an accepted analytical technique which had been successfully used in forestry.

They argue that using FORPLAN to allocate land and to schedule management simultaneously may have "raised LP to its level of incompetence," and that today the FORPLAN system produces:

- models which are too large, too poorly understood, and too costly to be of much value;
- models which do not adequately address the linkages among strategic, tactical and operational planning, and
- models which do not "recognize or comfortably fit the real process of making decisions on the National Forests."

Based on an extensive review of recent developments in operations research, Bare and Field conclude that separate models tailored to the strategic, tactical, and operational phases of planning hold the greatest promise for effective planning. They speculate that a misunderstanding of the planning problem may be the root problem and recommend that before any changes in analytical techniques are considered, "the relationship between planning and decision making in the Forest Service must be completely and satisfactorily resolved." They conclude that only then can a task force of decision makers, planners and analysts specify the "analytical support necessary," and can "issue bids for the purchase and installation of a "planning support system."

The questions posed and answered by Bare and Field are relevant. An operations research perspective requires an examination of both the structure of a system, and of the way it will be or was used. Bare and Field quickly abandon their self imposed restraint "merely to examine the mathematical apparatus" and they review the way FORPLAN was used by Forest Service land management planners. Their assessment of the implications of LP for forest management planning is incisive, their discussion of the questions posed is full of insights and wisdom, and their review of current developments in operations research applications to forest planning is a valuable guide to available tools. Their answers are plausible, and their conclusions, although severely critical, are mostly reasonable and constructive; but their arguments are not entirely convincing.

There are several weaknesses in their analysis: 1. They do not fully trace the consequences of violating the fundamental assumptions of LP; 2. Some key questions about implementation have gone unanswered; 3. Throughout their discussion they do not clearly distinguish between the problems and failures caused by the structure of FORPLAN and those attributable to the way FORPLAN was used.

We shall attempt to correct these minor deficiencies, and we shall do it in way which may be useful to those who in the future will be responsible for selecting, developing, and guiding the use of operations research techniques to plan the management of National Forests.

We shall present a simple but comprehensive framework for evaluating mathematical programming and simulation systems, use it to review and complete the evaluation of FORPLAN made by Bare and Field, and finally we shall show how this framework can also be used

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to evaluate a hierarchical planning strategy for implementing FORPLAN more effectively.

EVALUATION FRAMEWORK

The "framework" is simply three sets of criteria which address the questions: Is the computerized system SOUND--free of logical and programming errors? Is it OPERATIONAL--can it be, or has it been, used correctly and cost-effectively in planning? Is it RELEVANT--does it, or can it, meet institutional requirements and information needs? Note that this evaluation framework can be used either before, or after, a system has been implemented. The inspiration for this framework is clearly traceable to Bare and Field; however, it will become quickly apparent that it is sufficiently different from the three questions they posed to absolve them of all responsibility for its shortcomings.

Is the Computerized System SOUND?

Three principal criteria must be satisfied: is the system free of logical errors, are computer programs reliable, and can the system be used to generate models which are an acceptable representation of reality?

System Logic

For simulation models of the level of complexity required in forest planning, checking the logic rigorously is likely to be impossible or at the very least impractical. But for mathematical programming systems, the logic can be checked rigorously if adequate documentation is provided. It is essential this be done, and that errors be corrected, before the system can pass muster.

Program Quality and Management

Regardless of the level of competence of the programmers, some errors will remain in the large and complex programs typically used in land management planning (LMP). Programs must be designed to ease debugging, and to limit the consequences of errors caused by bugs discovered only after the analysis is under way, or is completed. Updates and extensions of the program rapidly compound the probability of serious errors, eventually requiring rewriting the code from scratch if reliability is critical. How the computer programs have been, and are, managed is a key factor in assessing the soundness of the system.

Representative Models

Computerized systems used in LMP result necessarily in simplified representations of reality. Simulation systems allow the designers great freedom in choosing the level of realism. The limit on achieving the most desirable level of realism in a simulation model is the cost of writing, and running, the simulation programs. This cost can be very high. Mathematical programming systems have additional restrictions which reflect their structure, and the algorithms available to solve them. For example, LP requires using only production processes which are "linear and independent." Linearity here means that outputs must be directly proportional to inputs, and that both inputs and outputs must be divisible into small increments, e.g. acres, dollars, recreation visitor days, acre feet of water, thousand board feet of timber. Note that a bridge or visitors' center is not divisible into small increments, and therefore cannot be represented in an LP. Independence requires that each production process be unaffected by the selection of any other process, even on adjacent areas. The implications of the restrictions imposed by mathematical programming must be worked out and evaluated to establish whether an acceptable level of realism can be reached. Finally, the data requirements of the system must be established, and assessed against the data which is likely to be available to intended users. The range of reliability of the of data is also very important. If some of the data required to run the system are accurate and others are less so, the reliability of the LP solution may be indeterminate, and the solution may confuse rather than inform.

Is the System Operational?

Can the System be run correctly and cost-effectively in operational situations? System designers tend to be optimistic about the capabilities of the hardware and software required by their brain children. They also tend to assume that users are, or will become, their equal in sophistication. So, we must now add: given the institutional setting, is the system likely to be used correctly and economically? The implications of the system's inherent characteristics must be re-examined in the operational context.

Is the System Relevant?

Does the system address the information needs, and is it consistent with institutional requirements? Information needs and institutional requirements are seldom well defined and, in the process of planning, they will be revised--perhaps radically. The system must have the flexibility to accommodate changes in needs and requirements. The capabilities of the system must be matched against initial needs and requirements, and inconsistencies identified (e.g. a system may be incapable of producing solutions which are both site specific, and globally optimum). The system must be usable in a way which will resolve such conflicts, or which will lead to acceptable compromises. This may require the elaboration of "planning strategies" for implementing the system. The validity of the analysis conducted with a technically sound system may well depend on the design of such planning

strategies. Several planning strategies for implementing FORPLAN are discussed below.

The three sets of criteria are closely related. For example the assumptions underlying a system determine its soundness, but they will also affect its ease and cost of operation, and the extent to which the system addresses information needs, and perhaps even institutional requirements. In FORPLAN, linearity and certainty assumptions lead to acceptable soundness only if extensive sensitivity analysis is conducted when the system is used. This is both costly and difficult, thereby affecting the operational rating. If the sensitivity analysis shows that the solution is vulnerable to departures from linearity and certainty, some information needs may not be adequately met.

The evaluation of a system cannot proceed simply by applying each set of criteria serially. Interactions must also be considered. Grouping the criteria is simply a way of organizing the immensely complex task of assessing the potential of computerized systems. It also brings into sharper focus the source of the problem: Is it the structure of the computerized system? Is it the way the system is--or will have to be--implemented? Is it the way information needs and organizational requirements are defined? Focusing on the source of the problem will help change the design or the implementation strategy of the system, and may help in finding a better system.

FORPLAN REVISITED

Let us now use this framework to review and complete the evaluation of FORPLAN presented by Bare and Field.

Is the Computerized System Sound?

Bare and Field limit their assessment of the soundness of the FORPLAN system to a discussion of the implications of the assumptions of LP for modeling management on National Forests. They propose that linearity and independence can be dealt with by "careful formulation of the model and cautious interpretation of the solution..." They note that LP is "deterministic"--that random variation in the data cannot be represented--and they suggest piecewise linear representation as a possible albeit expensive fix. Bare and Field conclude that these characteristics of LP do not pose insurmountable difficulties, and they proceed to evaluate FORPLAN, strictly based on the results of operational runs.

Bare and Field take for granted the conceptual soundness of the system. Because there has been no refereed publication on FORPLAN, an examination of the structure of the system is in order. If effort, talent, and professional integrity could assure the soundness of computerized systems, we could assume that FORPLAN were sound, and could dispense with further discussion on this subject. Because this is seldom the case, an examination is required, if only to identify those peculiarities of the system which users must know to run FORPLAN correctly, and which decision makers and analysts must understand to interpret the printout.

System Logic

Bare and Field infer from some "illogical results" obtained by Region 8 National Forests, that there may be something wrong with the model. They may be right. Yet, because they acknowledge that the complexity of the LPs rendered them opaque to analysis, we will never know unless the mathematical structure is systematically verified. This has been done by the developers, and a Mathematical Programmer's Guide for Version 1 has been published (Johnson 1986). A similar Guide for Version 2 is in preparation. Based on heroic--and only occasionally successful--efforts to work through the Version 1 Guide, we can only speculate that few will be able to gain useful insights into the mathematical structure of FORPLAN by referring to these Guides. The notation is cruelly complex, requiring infinite patience and stamina of those not blessed with a photographic memory. This suggests that even experienced analysts may not be able to deduce logically the relationships among the growing number of options available. Assuming there are no errors in logic, it will become increasingly unlikely that logical errors can be detected analytically if proposed extensions to the system are made. Detecting errors in logic by running sample problems is not an adequate substitute for rigorous analysis of the mathematical model. It is not likely to catch all the errors, and it is not cost effective.

There are other imperative reasons for presenting the model logic rigorously and in a way accessible to analysts. First, some available options--falling demand and Aggregate Emphasis/Coordinated Allocation Scheduling among others--require a clear understanding of the mathematical structure of the model to avoid potentially serious errors in formulating models and interpreting the solutions. Second, to permit an effective public review of National Forest land management plans, interested parties must be able to gain a thorough understanding of the analytical procedures used without unreasonable effort. The current Mathematical Programmer's Guide is comprehensive but so difficult to follow that its usefulness is questionable.

Computer Program Quality and Management

The probability of undetected programming errors is widely believed to increase exponentially as the number of modifications made to large computer programs increases. FORPLAN Version 2 has undergone twelve major updates at this writing. The implications for the FORPLAN matrix generator and report writer would be chilling were it not for the care and energy and expense which has been devoted to hunting and exterminating "bugs." Some legitimate concern about the existence of bugs must remain, requiring users to validate the FORPLAN solutions with great care. The implication is that FORPLAN models must be kept simple enough to make this validation practical and

affordable. A complete rewriting of the programs also may be appropriate to ease debugging.

Representative Models

Bare and Field wisely point out that computerized systems are not expected to produce "perfect model(s) of the real world," and that the greatest danger is that the system "is working less perfectly than the modeler (or client) thinks it is." This danger is very great in FORPLAN. Analysts are known to have a very low resistance to using options, especially when their use has been made easy by partially automating the data input. Analysts are likely to forget to keep on assessing the implications of the simplifying assumptions as they elaborate their models. Acceptable departures from reality in the early stages of model construction may rapidly become untenable as increasingly complex modeling options are exercised. For example, independence and linearity of production processes is quite a reasonable assumption when timber is the only output represented in the LP. In FORPLAN, linearity means that inputs and outputs are directly proportional (linear) to the number of acres managed with a prescription. Independence means that the inputs and outputs per acre of a prescription are unaffected by the choice of prescription for other acres, even if these acres are nearby or adjacent. These assumptions of independence and linearity become questionable when dispersed recreation--measured in Recreation Visitor Days per acre--is added to timber harvested; and these assumptions become quite unrealistic when tons of sediment, or acre feet of water, per acre are also added. Sedimentation rates, water flow, and recreation capacity are affected by vegetation manipulation on neighboring acres--which violates the independence assumption-- and are known not to be proportional to the number of acres managed--which violates the linearity assumption.

A fundamental question must be raised at this point: Is the relation between decision variables such as acres managed and recreation capacity--or sedimentation--sufficiently well known to describe it with the linear equations of LP? If knowledge is not sufficient, the imperative to promote a balanced analysis by including all quantifiable inputs and outputs in the LP must be resisted. For, to quote Holling and Dantzig--the father of LP--on Determining Optimal Policies for Ecosystems: "To develop an analysis which implicitly or explicitly presumes sufficient knowledge is ... to guarantee management policies that become more the source of the problem than the source of the solution" (Holling 1986). The inclusion of recreation, water, and sediment outputs in FORPLAN LPs may be based on presumed rather than actual knowledge.

The allocation/scheduling option has been proposed by the developers of FORPLAN as a logically sound way of dealing with the non-linearity and non-independence of some production processes such as recreation capacity, road construction, sedimentation and waterflow (Johnson 1986). But this would transform FORPLAN into a Mixed Integer Linear Program, and the typical forest-wide model could be solved--if at all--only at prohibitive expense. If FORPLAN is to be judged sound, the practical limitations on the use of its modeling options must be more clearly explained.

Similar limitations on the data used in FORPLAN are needed to preserve the soundness of the system. Because variability in the quality of the data cannot be explicitly represented, the quality of the data must be reasonably uniform. If it is not, the possibility that the results of the analysis are no better than the weakest data used in the model cannot be ruled out. Then the claims that LP can assure efficient allocation and consistency with Forest Service policies may not be sustainable when some of the data included in the FORPLAN LP are very soft. The implications are far reaching for a system which purports to model events into the distant future. To the inherent variability of ecological and economic data, the uncertainty of the future must be added. Thus optimizing, or constraining, linear combinations of outputs measured with greatly different accuracy over several decades casts a long shadow on the soundness of the system--a shadow which may be impossible to remove by the "careful interpretation of the solution" proposed by Bare and Field.

Is the Computerized System Operational?

In examining the question "Did FORPLAN work?" Bare and Field address mostly the difficulties encountered in solving FORPLAN LPs, and they identify size and density of non-zero elements as the principal culprits. They review the efforts to resolve these difficulties reported by Kent (1986) and conclude that "FORPLAN is taxing the LP state-of-the art" and that this should "be an incentive to consider alternative cures of the disease rather than (applying) more band aids."

The solution of large LPs has long been known to require "tuning" the algorithm parameters to the peculiarities of the model structure. This apparently has been done very successfully for Version 1 and 2 FORPLAN models (Kent 1986). Infeasibility of FORPLAN LPs, however, will remain a problem as long as large and complex models are formulated because errors in formulation cannot be entirely avoided in such problems. The greater the complexity and size of the model, the longer and costlier the process of finding and correcting these errors in formulation.

The cost of solving very large FORPLAN LPs is also noted by Bare and Field. It is not likely to fall in the near future. Expectations of substantial economies raised by the development of the Karmakar algorithm have not yet been realized; therefore, the prospects for FORPLAN LPs are not encouraging (Adler 1986). Large FORPLAN LPs are likely to remain expensive into the near future, and the prospects for solving FORPLAN models requiring a mixed integer algorithm are very dim except for models a fraction the size of typical forest-wide models. It is doubtful that site specific prescriptions can be included in the FORPLAN models without having recourse to mixed integer programming algorithms or special heuristic procedures. In either case, if the FORPLAN models are large, the cost and the difficulties in getting acceptable solutions probably will

defeat all but the most dedicated, and generously funded, analysts.

Comprehensive documentation is now available for Version 1, and soon will be available for Version 2. It is axiomatic that the documentation of large computerized systems is at best inadequate, and remains largely unread if not totally ignored. Nevertheless, we do need to be concerned here with FORPLAN documentation. The complexity of the system precludes a largely oral transmission of knowledge, and the large number and limited tenure of the intended users group insure that the documentation will be pivotal in assuring the correct and efficient use of the system. In documenting computerized systems, comprehensiveness while essential is not sufficient. The documentation must invite perusal by users, it must be made user friendly if the chaotic rule of Murphy's laws is to be avoided. The FORPLAN Mathematical Programmer's and User's Guides need to be revised to make them more inviting, or at least more accessible to users.

A complete assessment of whether FORPLAN is operational must await a thorough evaluation of the experiences of forest and regional analysts. However, the characteristics of the computerized system and of the documentation do provide clear indications of the potential problems discussed above.

Is the Computerized System Relevant?

Does it address the information needs and institutional requirements which finally emerged from this first round of planning. These needs and requirements have been identified earlier in this symposium.

Bare and Field's questions: "FORPLAN as a Model: Was it Right?" and "FORPLAN as a planning Tool: Was it Used?" both address the issue of relevance in a roundabout way. They are concerned that some models produced results which are "often illogical and in some cases illegal." From which they conclude that "If the model cannot avoid them without arbitrary constraints, then something is either wrong with the model or the policies that are being violated." The cases they cite, however, clearly suggest that the FORPLAN model confronted the planners with inconsistencies between economic optimization and administrative priorities and policies (to maintain stable budget and harvest levels). It appears that the FORPLAN model, far from being invalid, may have been teaching the analysts a lesson in forest economics, and properly may be credited with having forced analysts to reconsider notions of dubious validity.

By "used" Bare and Field mean: Was FORPLAN used "successfully in developing and supporting valid forest planning decisions that would not otherwise have occurred?" They conclude from discussions with users and decision makers that insights useful in decisionmaking--rather than answers--were gained. However, they report that the size and complexity of the FORPLAN models did not allow a rigorous sensitivity analysis of results--"except in the development of the preferred alternative."

The cases, interviews, and observations presented by Bare and Field provide an impressionistic basis for assessing the extent to which FORPLAN has addressed information needs and institutional requirements. Their analysis needs to be brought into sharper focus to derive guidelines for future planning.

The primary institutional requirement, that is to develop forest-wide plans consistent with management guidelines and based on an optimization procedure, has been satisfied for nearly all the National Forests. The remaining Forests are completing their plans with FORPLAN. Another institutional requirement also has been addressed with considerable success: to promote an integration of all the functional activities in the planning process. These are considerable achievements. However, when the attempt to integrate functional activities has been carried out by capturing all quantifiable outputs in the optimization process and in the constraint structure, it has created potentially serious problems. The size and the structure of the model has been greatly complicated in the attempt, often futile, to find linear approximations for production processes which are intrinsically non-linear, or for production processes which are still beyond the state of knowledge. The number of resource strata have been increased to represent differential conditions associated with the additional outputs. Prescriptions have been added to model the management of these outputs. The consequences may have been bloated models, and solutions of indeterminate reliability.

The Forest Service information needs were defined by lists of inputs and outputs, and indirectly by procedural planning requirements: analysis of the management situation, benchmark analysis, development of a range of alternatives. Strongly voiced but vague concerns for linkages with Program Planning, Program Development and Budgeting, and Project Planning also had some influence in defining information needs. Much, and on some National Forests most, of this information was extracted or derived from FORPLAN solutions. Is this information a bounty? Yes, but only if the data are reliable! There may be the rub. The statistical reliability of FORPLAN solutions is indeterminate. The data used in the models are known to vary greatly in precision. Reliability has been further compromised whenever the assumptions of linearity and independence have been stretched for the sake of capturing many functional activities in the FORPLAN LP models. We must also admit the high probability of errors in loading the data in the computer programs, especially in large and complex models, and the possibility of programming bugs and errors in system logic. Finally, we must recall that the uncertainty of the future has not been factored into the computation of the LP solutions. The reliability of the FORPLAN solutions to comprehensive, forest-wide models will therefore always be at best questionable.

The current incarnation of FORPLAN Version 2 (Release 12) is very probably free of logical errors, and of serious programming errors. Future extensions to the matrix generator and report writer programs may pose problems. The documentation while comprehensive is inadequate to check the logic and programming. The FORPLAN system is operational to the extent that it has been used successfully in the preparation of most National Forest land management plans. However, the cost of running FORPLAN may have been excessively high, and

the system too complex to master for many, perhaps most, forest level planners. The evidence pointing to the high cost and excessive complexity of FORPLAN discussed by Bare and Field--and that available to this reviewer--is admittedly anecdotal and fragmentary. But it reflects a concern often expressed by Forest personnel. A final determination of the seriousness of this concern must await a carefully designed survey of actual experiences by Forest level planners and line officers. While FORPLAN has addressed Forest Service institutional requirements, there are questions about the adequacy and reliability of the information computed with the system when large, comprehensive forest-wide models have been used. The assumptions inherent to linear programming may have been stretched beyond reason, the LP models may not have been adequately validated, and the solutions may not have been tested with the extensive sensitivity analysis required in applications of LP to ecosystem management.

Should we then use FORPLAN simply as an accounting device? Return to using simulation, or better yet, regress to the proverbial back of the envelope and the Austrian Formula? The excellent survey of available approaches given by Bare and Field does not hold the promise of attractive alternatives to FORPLAN. Besides, there are planning strategies which promise more reliable FORPLAN solutions, and lower costs, but at a price: giving up the impossible dream of comprehensive, site specific forest-wide optimization within the LP, and getting down to simpler models and more uniformly reliable data in the LPs.

PLANNING STRATEGIES

Bare and Field suggest that conducting the analysis of land allocation and of management scheduling separately might "be a more logical and understandable approach" which, while not guaranteeing "optimality...may well produce more understandable results which can be implemented in the real world." It is very doubtful that such a strategy would provide adequate estimates of the Allowable Sale Quantity (ASQ) on national forests where timber is one of the major outputs.

A similar strategy based on a multistage approach was used successfully on the Shoshone NF (Mitchell 1986). However, the Shoshone National Forest is not a significant timber Forest. Another strategy, using multiple smaller FORPLAN models which address critical issues such as endangered species, size of cuts, and roadless areas, already has been used successfully in Region 5 (Barber 1986). With both of these strategies, costs were substantially reduced, and there is reason to believe that the reliability of the FORPLAN solutions was greater than it would have been if a comprehensive approach had been used. Smaller, simpler models made a thorough search for errors practical, helped the validation of the solution against experience, did not stretch the LP assumptions beyond reason, and most importantly made a systematic and extensive sensitivity analysis practical, economical, and informative.

A third strategy is an extension of models designed specifically for planning the management of wildlands (Navon 1976, 1986). This strategy has been tested on a large private forest enterprise in Chile (Weintraub 1986), and it reflects recently conducted tests of a prototype method for systematically reducing the size of FORPLAN models (Navon et al. 1986). This hierarchical strategy makes a sharp distinction between "strategic" and "tactical" planning.

Strategic planning addresses policies (timber harvesting level, land allocation) and issues and concerns (protection of endangered species, allowable sale quantity, use of pesticides/herbicides, designation of roadless areas). Tactical planning determines how policies will be carried out, and how issues and concerns will be resolved by scheduled and site specific management activities.

Strategic planning is properly conducted at the forest-wide level. It must extend over at least a full rotation, a time span sufficient to assess the long range consequences of policies and of decisions driven by issues and concerns. The sheer scope of the task suggests that the resources be roughly stratified, the management options kept few, and the production processes defined only by critical inputs and outputs. This level of resolution is consistent with the type of decisions taken by the Forest Supervisor, and is also consistent with most of the information requirements of the Forest Plan.

Tactical planning is bounded by the decisions of strategic planning and is most effectively conducted at the District, the lowest level responsible for on the ground management. The time span can now be more limited, say to the horizon of program budgeting. Only the management options available in the next few years need be considered in detail, but production processes must now be defined in sufficient detail to permit adequate accounting of on the ground management costs and of accomplishments. Note that the timber sale schedule required for the Forest Plan is clearly a tactical planning objective. Therefore, the Forest Plan requires both strategic and tactical planning.

Let us sketch how such a hierarchical strategy might be used with FORPLAN to prepare and implement the Forest Plan, and note how it differs from the current strategy of attempting to do site specific, comprehensive, allocation and scheduling for the entire forest in a single FORPLAN LP model.

Step 1.--Build a small and "crude" forest-wide FORPLAN model for strategic planning, with resource strata acreages, prescriptions, and plausible ranges for critical inputs and outputs provided by each District. All the data required for such a model are available on Forests which have run FORPLAN models. The current level of resolution does, however, need to be lowered to conform to the thrust of strategic planning: policies, issues and concerns. Analysis areas must be combined, the number and scheduling choices of the prescriptions reduced, production processes represented only by dollars, timber, other critical inputs and outputs for which reliable data is available, and by proxy indices for outputs for which reliable data are not available. The objective function and constraints must also be specified with explicit consideration for the reliability of the data.

Step 2.--Conduct an analysis of policies and issues with the Strategic forest-wide FORPLAN model: compute

Benchmarks and the set of Alternatives from which a Preferred Alternative will be selected. FORPLAN LP model solutions will have to be complemented with estimates of inputs and outputs not included in the LP. The FORPLAN LP solutions may have to be revised based on professional judgment, or recomputed after prescriptions or constraints have been modified to accommodate the production of the outputs not included in the LP. This process, while not optimal in the technical sense, promises a level of efficiency consistent with the state of knowledge and data available.

To insure that each Alternative can be implemented, it must be validated by every District. This can be done by allocating the solution of the forest-wide model among the Districts. FORPLAN report options are already available to do this. Changes requested by Districts may occasionally require solving additional forest-wide LP models. Iterating between the District and Forest can be minimized by imposing constraints on some District inputs and outputs in the FORPLAN forest-wide LP model, and in the computation of the levels of the outputs not included in the LP model.

Step 3.--Once the Preferred Alternative has been selected, each District can conduct a site specific analysis of management options, at a level of detail consistent with its information needs and its planning resources. The data available on most National Forests may provide an adequate level of resolution. Data resolution can be refined selectively to meet specific management needs, e.g. to develop recreation areas, to plan timber sales for the next 5 or 10 years, and to manage the roads and trails network. The analysis can be conducted in part, or largely, within a FORPLAN LP model. This model still would be very much smaller than current forest-wide models. It would span fewer years and many fewer acres. Management options for the next decade are severely limited by past commitments, and by the first hand knowledge of the District staffs of what is practical. Therefore, detailed prescriptions will be required only for a fraction of the District acreage blanketed with prescriptions. Furthermore, prescriptions need reflect only the guidelines imposed by the Preferred Alternative. With these small District models, the use of FORPLAN options for representing site specific management activities (road networks, Coordinated Allocation Zone, etc.) could be practical and cost-effective.

How sound, operational, and relevant would such a planning strategy be if both the forest-wide and the District models were prepared with FORPLAN? How much of an improvement could it bring to forest-wide planning and to Forest Plan implementation?

Sound? Whatever logic and programming errors remain in FORPLAN still would be a problem. However, with simpler and smaller models it would be easier to recognize and track down pathological system behavior and aberrant results. Assumptions would not be stretched as taut as they often are now. Policies, issues, and concerns could be effectively analyzed with a "what-if" process, thus eliminating the necessity of including all the inputs and outputs relevant to multiple use management in the same LP. Besides, with simpler and smaller models, a few of the non-linear processes now could be correctly represented in the LP by special integer variables, and models still could be solved at reasonable cost. The certainty assumption would not cast as long a shadow, because with small models, what-if runs could be used to test the robustness of solutions over ranges of future natural and economic events.

Operational? The cost of processing and solving many small LPs still would be substantial, but would be very probably much lower than for processing fewer larger LPs. Savings in generating and interpreting solutions, and particularly in debugging models, would be large and likely. Automated data processing costs also may be reduced: the simpler structure of both the forest-wide and the District models would not tax the expertise of analysts and planners as much. Fewer runs would have to be redone. Substantial reductions in solution costs also could be realized using techniques for shrinking FORPLAN models currently under development (Navon 1986). These techniques work most effectively on models whose structure is only moderately complex. As experience is gained, models may be sufficiently reduced in size and complexity to solve them on microcomputers, greatly reducing turn-around time and costs. Complementing the forest-wide model solutions to factor in critical inputs and outputs not explicitly represented in the LP could prove to be difficult and costly, but is not likely to swamp the savings from reducing the size and complexity of the FORPLAN LP models.

Relevant to institutional Requirements? The forest-wide and District models would still promote the integration of all the multiple uses of the forest in the planning process. Explicit representation in the LPs of every use is not necessary, it can even be counterproductive. When reliable information is not available on some uses, or when management for these uses cannot be plausibly approximated by linear production processes, including these uses in the LP gives only an illusion of multiple use planning. Substituting a greater measure of professional judgment for computerized analysis in the elaboration of Benchmarks and Alternatives is likely to strengthen planning. But would the optimality requirement of the NFMA Regulations be satisfied? At least as well as with large comprehensive models, and in all probability much better. The objective functions optimized in comprehensive models are a heroic attempt to do an impossible task. The level of optimization achieved may well be indeterminate, because the reliability of the data in the FORPLAN solutions are unknown. At least with smaller and simpler models, the reliability of the solutions could be established and a measure of efficiency could be legitimately claimed. Therefore, the institutional objectives to promote integrated resource planning and to optimize net social benefits may be better served by less comprehensive models.

Relevant to information needs? Current FORPLAN models tend to overwhelm the Forest Supervisor with detailed information and yet do not provide District Rangers with sufficiently detailed, site specific data for implementation. With a hierarchical strategy, each model would be focused on a single level of decision making. Each model would provide information in terms directly relevant to the decisions over which the Forest Supervisor and the District Ranger have primary responsibility and control: allowable sales quantity, roadless area designation, roads and trails development, etc., for the Forest Supervisor; use

permit and timber sales administration, project planning, etc., for the District Ranger. The stakes of Supervisors and District Rangers in land management planning would be increased, and, if so inclined, these line officers could fully understand and gain control of the FORPLAN models.

A hierarchical strategy is not without costs. Line officers, already burdened with heavy responsibilities, must participate actively in a hierarchical planning process. Incentives must be found to induce planners to keep the FORPLAN models small and simple. Hierarchical planning only makes such models possible. Some loss in optimality will be incurred. The losses in present net value are not likely to be statistically significant given the softness of the economic data available for forest-wide planning. Losses in the timber allowable sales quantity will occur and may pose a more serious problem. Statistical analyses will be needed to determine their significance. Preliminary results suggest that very substantial reductions in model size may be achievable for reductions in allowable sales quantity which are probably not statistically significant (Navon et al. 1986).

Long before the next cycle of forest-wide planning begins, some Forest Plans will have to be revised. Some alternative to forest-wide, comprehensive, site specific allocation and scheduling is needed to make FORPLAN a more reliable and cost-effective planning system. A promising strategy is to use separate FORPLAN models to address the information needs of the Forest Supervisor and District Rangers. The proposed hierarchical strategy is very sketchy, and its evaluation is admittedly somewhat superficial. Additional work is needed to establish its usefulness. In particular, the linkage between the forest-wide and the District models requires further elaboration and scrutiny, and a rigorous statistical analysis of the consequences of reducing data resolution in the forest-wide model is needed. The objective here is only to start a discussion of ways and means to improve the cost-effective use of FORPLAN.

A complete evaluation of FORPLAN must await a survey of the experiences of planners and decision makers on National Forests. Nevertheless, the structure of the computerized system, its documentation, and the fragmentary reports on its field use, do point to problems and to opportunities for improving the way FORPLAN can be used to elaborate implementable forest-wide alternatives. A hierarchical planning strategy holds great promise for grasping these opportunities.

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FORPLAN: Does It Meet the Statutory Requirements?

Charles F. Wilkinson[1]

Although we are in a transition stage, the domination of timber harvesting in the National Forest System is ending. Within roughly 8 to 10 years, the national allowable cut will begin to drop steadily but slowly. Within roughly 15 to 20 years, the cut will become stable at a substantially lower level than it is now, probably 20-25% below the current figure of 11 billion board feet. Then the phrase multiple use, may still be in the law; but it will have been replaced in common discourse and very likely in codified law also by a concept recently coined by [former] Arizona Governor Bruce Babbitt. His phrase for the new doctrine of land management on both Forest Service and BLM lands is "public use."

The national forests are run by a blend of economics, recreation, wildlife biology, power politics, minerals policy, ecology, silviculture, local color, wilderness philosophy, hydrology, law, romanticism, and the institutional personality of what is probably the greatest and most interesting resource agency in the world. Such diverse sources have defined the almost incomprehensibly large package of benefits received from these lands.

Several trends suggest new directions in forest policy. A growing number of states are opposing Forest Service timber practices. The curricula in the forestry schools over the past 15 years has broadened; many of those schools have been redesignated as natural resource colleges. Western guides and packers are becoming more hostile toward Forest Service programs. Public awareness of the interconnectedness of all resources is increasing, especially the way most extractive development affects water. American Indians are becoming more involved in Forest Service disputes. The State of Montana concluded in it's 1986 water quality report that "accelerated road building and timber harvest on U.S. National Forest lands now pose the single greatest threat to aquatic life in Montana." More small land owners once cherished but are now angered by the location of their summer homes on land bordering the National Forests. The public is participating in National Forest policy more. The population in the American West is increasing, many of the new arrivals are attracted to the public lands. The State of Colorado concluded this year that the National Forests in Colorado produce $4 billion in recreational benefits. There is a growing perception among observers that the rationale for the high level of subsidized below-cost sales lacks integrity. The young people hired by the Forest Service during the past decade have differing philosophies. There is a new appreciation for pacific salmon and steelhead resources and the effects that logging and roading can have on them.

Several sketches can be presented fairly that show very different things. They include: (1) the widely held idea that we need to extend a hand to residents of small timber-dependent communities; (2) a possible upturn in housing starts; (3) the potential of a greatly increased demand for American wood products in third world nations; (4) the success of [Oregon Senator] Mark Hatfield, as able and visionary a person as there is today in public policy anywhere, in using the appropriations process to raise the cut in Region 6 from 4.6 billion board feet to 5.2 billion board feet during this fiscal year.

Those and many other such examples could be given. But the first set of trends gives a truer picture, not of all future policy, but of irresistible forces that will be accommodated by Forest policy and that will cause a gradual nondisruptive decline in the allowable cut.

Last year, Governor Babbitt, in an address to the annual convention of the Sierra Club in San Francisco, noted that in 1903, President Theodore Roosevelt met with John Muir in Yosemite National Park to talk about the preservation of wild land. Babbitt, often critical of the current administration's natural resources policy, concluded his talk by hoping that the time would again come when the Presidents of the Sierra Club and of the United States would meet in Yosemite. But the heart of his talk was,

> "We need a new western land ethic for nonwilderness. The old concept of multiple use no longer fits the reality of the new West. It must be replaced by a concept of public use. From this day on, we must recognize the new reality that the highest and best, most productive use of western public land will usually be for public purposes, watershed, wildlife, and recreation. The move to public use of the climax of a long historical process. The Homestead Act of 1862 recognized that public lands should be used to facilitate settlement and development. Seventy years later having served that purpose, the public domain was closed to homesteading. The next phase in the evolution of public lands was private resource development. The Mineral Entry Act, the Timber Entry Act, and the Reclamation Act of 1902, put the public lands up for mining, grazing, logging, and water development. We are now at the threshold of the final stage in the evolution of public lands policy. The great urban centers of the West are filled with citizens who yearn for solitude, for camping facilities, for a blank spot on the map, for a place to teach a son or daughter to hunt, fish, or simply survive and enjoy. The time is at hand to go beyond multiple use. Mining entry must be regulated. Timber cutting must be honestly subordinated to watershed and wildlife value. And grazing must be subordinated to regeneration and restoration of grassland. Many of the Forest Service and BLM plans now being circulated ignore the primacy of public values. It is now time

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to replace neutral concepts of multiple use with a statutory mandate that public lands are to be administered primarily for public purposes."

This concept is likely to shape public debate in this field over the course of our careers. Conceptualizations of policy have always mattered, whether it was manifest destiny, all the way through the sagebrush rebellion, including multiple use. I expect that public use could become in that category. It's important, though, to recognize what Babbitt did not say. He recognized and would affirmatively advocate that extractive uses such as timber harvesting, mining, and grazing must continue. But they should be as he put it, "honestly subordinated to public uses." Implicit in his formulation are two ideas about multiple use. First, that multiple use, perhaps unlike sustained yield, has little substantive content. It doesn't tell you which choices should be made. Second, multiple use has tended to produce, depending upon the region, domination by timber grazing, mining, and water development interests. Public use would not and should not erase those uses. But it would produce them. The reduction in allowable cut that I think will come is an example of public use. A draw down of 25% of the total cut would greatly ameliorate the key stresses that we now see on public uses.

How is the Forest Service reacting to these pressures already in place that may lead toward future recognition of public use? The returns are mixed. The first is a decision handed down by the Ninth Circuit Court of Appeals in San Francisco earlier this year. The Forest Service manages Lake Shasta in northern California. It's a major recreational resource and has had houseboats on it in the past. The Great American Houseboat Company began to sell time-share units on houseboats, making them kind of floating condos. The Forest Service, realizing that this would greatly increase the user days on the lake, combated the sure overcrowding by adopting a permit system outlawing most time-share ownerships in houseboats on Lake Shasta. The Forest Service had no specific authority to do that in the statutes. The Appellate Court upheld the Forest Service's permitting system. Ruling that the agency's power to regulate "occupancy and use" within the forests, tracing back to the 1897 Organic Act, was broad enough to encompass the houseboat regulation for which again there was no express support in any statute.

In a second example, the agency has acted in an opposite way. The Hard Rock Mining Law of 1872, perhaps the most outmoded of any public lands statute enforced today, allows hard rock miners the right to enter most public lands, and if they make a strike, to receive title not just to the minerals but to the overlaying 20 acres of land also. What that Act did was to zone the public lands for mining. The previously unrestricted autonomy of miners has been cut back in many ways partly because of the many environmental impacts from poor mining practices. However, the Forest Service, in many cases, is refusing to take the tough steps. If you talk to Forest Service mining officials in the field, you find that their marching orders are that they may "regulate" miners, but they cannot deny to them the right to mine, even if miners refuse to comply with all necessary Forest Service requirements.

As Professor John Leshy of Arizona State University Law School concludes in his upcoming book on the Hard Rock Mining Act, the Forest Service is far too tender toward industry on this issue. There is no absolute right to mine. The Forest Service ought to assert maximum management authority while exercising it fairly and reasonably over this major class of forest users.

Third, the Forest Service has made what seems to be a truly unfortunate set of decisions on key issues relating to water pollution. The so called "Go-Road case" was handed down last year, and then a slightly amended opinion was reissued this last summer. The Ninth Circuit Court held that proposed logging and the Go-Road itself on national forest lands failed to meet California water quality standards to protect against erosion.

The Forest Service argued that it required loggers to follow so called best management practices (BMPs), such as requiring buffer strips and setting soil types in gradients where logging may not occur. But the Ninth Circuit Court said that BMPs are only a means to an end, and that loggers must meet California's substantive standards such as its requirement that turbidity cannot rise more than 20% above natural turbidity when the additional turbidity is caused by development activities. The state turbidity standard, the courts said, is an end, not a means, and it must be complied with. A great conservation agency, especially one aware of the fragility of anadromous fish runs, and especially an agency recently chastened at Mapleton, should have applauded that decision as a key element in our continuing and frustrating struggle to find reasonable ways to reduce erosion from non-point source pollution. Instead, the Agency recently went to EPA and sought to have the Go-Road ruling administratively overturned.

In 5 to 10 years, maybe sooner, the kinds of restrictions that California, and Idaho, and Montana, and others are enforcing for erosion will be accepted as a matter of course, in my view. Our rivers require those kinds of standards, and so do the animals in them. But instead of being in the vanguard of an irresistible movement, the Forest Service went into the bunker on that issue.

Another example is very different. In Region 6, the Pacific Northwest, the Forest Service has gone to great lengths to follow the scientific evidence to protect old growth habitat, by using the spotted owl as in indicator species. Tremendous political pressure has been exerted on the agency to alter its proposals. But the agency has shown a great deal of courage at several points in this process, and more often than not, has followed expert scientific conclusions.

Let me finish then by drawing out some very broad directions that the Forest Service might take if I am correct about our already being into the beginning point of an evolution into public use. The Forest Service ought to do two basic things. It ought to consolidate it's authority, and it ought to be a leading advocate for good resource policies when public uses are threatened.

We will learn a lot about the Forest Services willingness to consolidate it's authority, whether it will act as it did with houseboats on the one hand or with hard rock mining recently on the other. And we will learn about it's willingness to act as an advocate within the next few years

in regard to a proposed water project that is just about 40 miles southwest of here - the proposed Two-Forks Dam.

Denver and other metropolitan users want to build a 550-foot-high dam and flood some 22 miles of Blue Ribbon Trout Stream in the South Platte River Valley. The draft EIS will be out in a month or two. There are many signs that this is an old-style western water project, perhaps one of the last ones to be proposed--one that is economically and environmentally unsound. The Forest Service staff has worked diligently on Two-Forks in terms of conducting research and analyzing the many issues involved. Two-Forks would be within Roosevelt National Forest and would require the issuance of Forest Service permits. But the question is what the Forest Service will do after the EIS comes out.

The Forest Service for too long has failed to have a water policy, despite its broad occupancy and use authority upheld by the courts. The supposed rationale of the Forest Service of deferring to state water law is bankrupt. The defiance of California, Montana, and Idaho state water pollution laws shows that. The Forest Service ought to bring to an end it's abdication in the area of western water. It ought to participate fully in the making of western water policy in a number of different ways, just as it participates in the making of western timber policy. We will begin to see with Two-Forks whether the Forest Service will take a position as a leader on western water, always and ever the leading resource issue out here.

Top officials also ought to begin developing in earnest, or perhaps continue developing, a program that will deal with agency financing of the National Forests if harvest levels taper off. A good slice of revenues from different development programs go into the Reclamation Fund which will not much be used in the future. Perhaps adjustments should be made there. Mineral leasing programs from National Forests don't go back into the forests. Maybe all or part of those funds ought to go into the agency's budget. Fees need to be explored for all users, including recreational users, seriously. Whatever the specifics, an amended system of revenues needs to be developed now to deal with changing times.

The Forest Service ought to continue its struggle over what is in some ways the ultimate issue for it as an agency, which is to reclaim its historic independence. Over the past 15 years, the Agency has lost control in various contexts - to the Assistant Secretary's Office, to Congress, to the courts, to industry, and to environmental groups. Ironically, the Forest Service has begun to regain independence in some situations by bringing in outside mediators. Mediation has worked in a few situations. When it does, it brings the Agency closer to its public, closer to the mission of fulfilling public needs through consensus. But, in general, authority recently has trickled away caused by and accompanied by, a loss of credibility.

For a substantially independent Forest Service, finding answers mainly from the sciences and from public input has a proven unique potential for good results. Perhaps it is time for a second Pinchott letter.

One thing was probably cemented by yesterday's election. We will not soon return to the excesses of the administration in the area of natural resources policy. I don't say that in a partisan way. I see no basic distinctions between the Nixon, Ford, and Carter administrations in natural resources. But I do see differences between those years and Burford, Crowell, and Watt. Yesterday's results tell me that the next administration of either party will be ready for progressive, future-looking policy initiatives.

The new Assistant Secretary ought to go the the Chief and request the Chief to draft a letter to himself from the Assistant Secretary. The letter ought to set out in ringing terms what it is that the Forest Service stands for, what it is that it as an institution believes in. It ought to be an evocative statement that goes beyond planning, beyond net public benefits, and beyond acting as a referee. It probably ought to speak of public use because that is probably where the future is. This would return authority and independence to the Forest Service.

A strong, independent Forest Service can be the best trustee for these lands, and the Forest Service has always been strongest when it has used the sciences to listen to the commands coming up from the ground and when it has been the champion of the future, not the captive of the past. I hope we soon begin a far-ranging debate on whether public use really is the concept of the future. If it is, I hope that the Forest Service will fully embrace it exactly as a great conservation agency should.

Closing Remarks

FORPLAN: An Evaluation of a Forest Planning Tool -- A Summary

Roger A. Sedjo[1]

Abstract.--FORPLAN has potential to be useful as a decision making tool in public forest management, but this potential has not yet been realized. The model needs to be used for more limited purposes in simpler and smaller forms. Also, FORPLAN should be supplemented with more specific analytical tools which have tactical and on-the-ground applications.

In this "summary" I recount briefly some of the major points raised by the papers of the conference that make up this volume--their similarities and their differences--and then identify the consensus that I perceived as emerging over the three days of the symposium. Some persistent differences will also be noted. While the symposium was designed to focus on the FORPLAN model, the discussion showed that it is often difficult to untangle the model from the planning process, and the planning process from the plan. This summary will range beyond the model, thereby reflecting the nature of the discussion of the symposium. The symposium evaluation of FORPLAN reached much consensus during the three days of the meeting. This paper will focus on that consensus.

Overview

The first one-and-one-half days presented a useful review of the variety of political, legislative, interest group, bureaucratic, technical and other background considerations that influenced the development of FORPLAN and its use in Forest Planning. The relationship of the predecessor models such as Timber RAM and MUSYC and the tendency of FORPLAN to incorporate new types of models into its broad perspective was noted. Also, the role of the Committee of Scientists was discussed. While many of the individual groups and events were familiar to most who attended, a discussion of the role of these events in the development of the FORPLAN model provided a useful backdrop for the remainder of the symposium. Some presentations were used to show the broad applicability of FORPLAN to non-Forest Service users. In the process, the FORPLAN model was described as being a software package which has broad usefulness because of its flexibility for many applications. Examples of its use included applications by industrial firms and applications to Third World countries. We also learned why FORPLAN was not applied to certain regions, for example, British Columbia.

The major focus of the meeting, however, was on assessing the usefulness of the FORPLAN to help in public forest planning in a context such as in the U.S. where multiple-use considerations dominate and the forest is used to produce a variety of outputs, both priced and nonpriced.

Criteria of Success

The discussion of the first one-and-one-half days was descriptive and largely positive. The application of the FORPLAN to the Shoshone National Forest was used as an illustration of the model's ability to help in the development of a plan and in decision making. In the Shoshone, FORPLAN provided input into the decision to move ahead with certain activities that were controversial but sensible. More generally, some of the early presentations characterized Forest Planning, and by inference FORPLAN, as a success.

This raised the question of what constitutes a success. Several criteria emerged. Out of the legislative activities that surrounded the Resources Planning Act (RPA) and the National Forest Management Act (NFMA) came two objectives that the legislation was designed to achieve. These were (1) the reduction of conflict, or more broadly what I'll term a political criterion, and (2) the improvement of decision making regarding the national forests. These objectives can be viewed as criteria with which to evaluate the success of forest planning and also by inference the FORPLAN.

Other goals and criteria also might be considered. For example, a former Associate Chief of the Forest Service has cited an important effect of the planning process as that of helping the Forest Service in the budget process. Norman Johnson, in his luncheon address, suggested that the FORPLAN has functioned to protect the Forest Service from its critics by providing a shield of technical jargon with which many critics cannot effectively deal. (This view, however, was vigorously contested.) Similarly, planning may have had the positive effect of forcing the Forest Service to take an integrated view of all of its resources, not just

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timber, and to force the explicit consideration of economic and biological considerations. Others noted that the FORPLAN has led to staff training and increased technical expertise. While all might not agree that the above outcomes of the FORPLAN and the planning process were among the goals, stated or unstated, these types of effects have occurred, and have resulted in labeling the process as either a success or a failure.

Reduce Political Conflict

Reducing conflict was one of the stated goals of the planning process. How well have we done? Conflict persists, but probably no more (and possibly less) than without planning. The Beuter/Iverson paper seems to see FORPLAN and the planning process as a success largely in political/ conflict terms. Similarly, Binkley's comments suggest that conflict related to the National Forests may have been reduced since the advent of planning. While not eliminating conflict, the planning process may have provided a point upon which the conflict may focus. It may have allowed the conflicts to proceed in a more orderly, less chaotic fashion. It is too early to know whether conflict has been reduced or merely rechanneled or perhaps postponed. While the question still awaits the future for a definitive answer, the preliminary assessment is that conflict has been reduced.

Improved Decision Making

Has forest planning and the FORPLAN model in particular led to improved decision making? If the answer thus far is negative, does it give promise of leading to improved decision making in the future? As noted above, FORPLAN received high marks for its usefulness on some forests, e.g., the Shoshone. However, over the course of this symposium the FORPLAN has also received a host of criticism. A recurring criticism has been that the model, as typically applied in forest planning, is too large. The criticisms of large models are of two types, general and technical. The general criticisms include:

1. the models as developed are beyond the capability of most of the staffs;
2. the models tend to dominate the intellectual effort of the staffs and, therefore, preclude use for analysis and stifle creativity;
3. the FORPLAN exercise tends to dominate, becoming the plan rather than the tool;
4. FORPLAN often is used to justify site specific actions beyond its design or capability.

In summary, the criticism was that in trying to be comprehensive and include everything, the model lost its ability to be a useful, flexible and perceptive analytical tool.

Other specific criticisms included that of the Beuter/Iverson paper, in which they stated that they did not know if it improved decision making, and Binkely's paper where he contrasted seven costs (unweighted) of the FORPLAN with only two benefits. Another often-expressed concern was the lack of a budget in the planning process. The absence of a budget to give a scale of the relevant range of a plan could lead to serious errors in the mix and level of planned forest outputs.

Several specific technical criticisms also were directed at the model. These included technical problems related to its size, problems related to linearity, lack of validation, data problems--especially when dealing with data with large but unknown variance, etc.

Toward Improving FORPLAN

Despite the criticism, there was also considerable support for the FORPLAN model, in concept, as an analytical tool. There seemed to be general agreement that:

1. FORPLAN could be useful as a "strategic" model to provide a broad overview.
2. The model should be kept small and of minimum complexity.
3. Other tools and models ought to be used at the tactical and implementation levels to complement and supplement FORPLAN.

The model should be kept small, manageable, transparent and understandable. In essence, the "white box" approach is preferred in which the projections are either intuitive or, if not, the counterintuitive results can adequately be explained be tracing through the model. Currently, FORPLAN is typically a "black box," the output of which often cannot be explained and therefore must be accepted on faith. When dealing with counterintuitive results, the decision maker has no way of knowing whether the result is an artifact of the model or if it represents a complex but sensible reality. In this context, a good decision maker would tend to discount or wholly ignore such counterintuitive results. Such a response seriously reduces the model's value as an analytical tool.

Conclusions

While FORPLAN has potential to be very useful as a decision making tool in public forest management, this potential has not yet been realized because of the model's tendency to be overly large and comprehensive. To be useful the model needs to be used for more limited purposes in more simple and smaller forms. In addition, the FORPLAN tool should be supplemented with a variety of more specific analytical tools that have tactical and on-the-ground applications.

Concluding Remarks and Symposium Summary

John Sessions[1]

Abstract.--The major points of discussion are summarized in terms of FORPLAN's ability to (1) improve the planning process, (2) improve communication, and (3) improve decision making. There was general agreement that FORPLAN met the analytical requirements of the National Forest Management Act. The sharpest criticism was the inability to model nonlinear relationships and operational difficulties with large models. Several variations of hierarchical planning were suggested. Additional analysis beyond the forest-wide FORPLAN analysis appears to be needed.

The objective of this symposium wasto document and evaluate the implementation of FORPLAN. I will not attempt to summarize each speaker's paper as this has been excellently done by the various discussants and my co-panel member, Rodger Sedgo. I will try to identify the major areas in which the speakers and audience participants agreed or disagreed and suggest where we might go from here.

Using the framework suggested by John Beuter, we can evaluate the success that FORPLAN has had in (1) improving the planning process, (2) improving communication, and (3) improving decision making.

Concerning improving the planning process, there was general agreement that FORPLAN met the analytical requirements of the National Forest Management Act (NFMA). Teeguarden suggested that some type of mathematical tool would have been required to meet the analytical requirements of NFMA. Wilkinson commented that the level of analysis in FORPLAN exceeded the requirements of NFMA.

There was general agreement that certain issues needed to be dealt with outside of the model. Teeguarden rated the ability of FORPLAN to achieve the planning requirements into 16 categories and concluded that the weakest categories were in linkages to issues outside of the forest such as the demand curves facing the forest which involved regional linkages and regional cumulative effects. Shugart agreed that FORPLAN adequately could represent the ecological linkages if adequate estimates of the yield coefficients were provided using small scale ecological models and large scale ecological models used to verify the total FORPLAN "solution." All speakers recognized the limited ability of a linear programming model such as FORPLAN to model spatial relationships but agreed that it was not a fatal flaw that could not be achieved by some form of later analysis outside of FORPLAN. There were some concerns among participants, however, about how watershed, recreation and mineral resources were being addressed within FORPLAN and these questions went unanswered.

There was considerable discussion about whether FORPLAN improved communication. Communication takes place at three levels; within the planning team, between the planning team and the Forest Supervisor, and between the Forest Service and public. There was general agreement that FORPLAN could enhance communication between the planning team and the Forest Supervisor, but the Forest Supervisor would need to remain in close contact with the team to understand the complex modeling relationships, implicit and explicit assumptions.

Within the planning team, FORPLAN provided a common framework for specialists to communicate and to see that their concerns were integrated into the plan. There was disagreement about whether communication between the public and Forest Service was improved using FORPLAN. It was suggested that because of its complexity FORPLAN might be used as a shield between the Forest Service and the public to justify agency positions. Others, such as Binkley, reasoned that the standard approach to analysis provided by FORPLAN increased the ability of large centralized interest groups to follow the analysis more easily after some initial investment in model study. Mealy cited examples where the public participation increased with the ability of the public to work together with the planning team in putting together prescriptions and seeing the total results in a forest context.

There was general agreement that FORPLAN was not the Forest Plan, but a tool to aid decision making. Daniels and Mealy felt that FORPLAN aided decision making. Davis proposed using FORPLAN in a "with" and "without" application to measure the improvement in decisions. He suggested doing this on a smaller scale in industrial applications. Greg Jones, using the Integrated Resource Planning Model (IRPM), recently completed a similar experiment to measure the efficiency of alternative planning methods in the northern Rocky Mountains. Jones found large increases in efficiency could be gained when spatial relationships were important.

[1]College of Forestry, Oregon State University, Corvallis.

The sharpest criticism of FORPLAN came from the operations research panelists including Bare, Fields, Dykstra, and Navon. The operations research group agreed that the major shortcomings in FORPLAN were the same as in any large linear programming model. These limitations were assumptions of linearity in modeling reality, the difficulty of identifying measurement errors, and the cost of running the very large models. All four operations researchers proposed a hierarchical approach to forest planning to reduce model complexity and increase the ability to analyze the problems specific to that level of planning.

There was agreement that one or more additional levels of analysis would be needed besides a forest-wide application of FORPLAN. These added levels of analysis might take place above and below the forest level to meet specific needs. At a higher level, analyses might establish guidelines for FORPLAN-forest applications. This has been proposed before in terms of a regional plan.

At a lower level, more site-specific planning could be done to insure the plans are implementable and to provide detailed information for short-term budgeting. This need for a tactical plan is becoming more widely recognized throughout the Forest Service and is being termed "area analysis."

I concur with the previous speakers' concerns about hierarchical planning. FORPLAN must be considered a strategic planning model. Many of the current problems facing public forestry cannot effectively be dealt with by strategic planning models. Problems that require spatial, site-specific analysis can only be cursorily considered in forest-wide planning models. Typical issues include "sales below cost" and "cumulative effects".

It seems that the focus will shift from strategic planning which concentrates on estimating average effects over the forest for the long term (100-200 years) to tactical forest planning that concentrates on estimating site-specific effects for logical geographic areas for the short term (5-50 years).

This tactical planning involves a comprehensive, in-depth analysis of the projects that should be selected for an area over the next few years or decades given certain objectives and constraints. Spatial analysis, estimation of site-specific effects and detailed consideration of logging and transportation choices are important facets of this approach.

Very little research, development, training and extension is being conducted on tactical forest planning. Much of the recent research and development has centered with the Management Sciences Staff under the direction of Mal Kirby. One notable output has been the Integrated Resource Planning Model. Work on increasing the efficiency of this model is being done by Greg Jones at the Intermountain Station. Outside the Forest Service, universities occasionally have projects that touch on tactical forest planning, including Teeguarden's work on the economical suitability of timberland and my own work on designing road systems to efficiently access a specified set of cutting units.

Johnson and I have previously proposed research on tactical forest planning to the Forest Service. The needed work in tactical forest planning includes:

(a) What questions a tactical planning model should answer.

(b) An evaluation of the ability of existing models, such as IRPM and FORPLAN (Version 2), to answer these questions.

(c) Design changes in these models to make them effective in tactical forest planning, or design new models to do these tasks.

(d) Development and evaluation of different types of linkages between these planning models and geographic information systems.

(e) Design changes in tactical planning models and geographic information systems to make a smoother and more informative linkage.

(f) Development and evaluation of different types of linkages between strategic and tactical planning.

(g) Analysis of different policies that can be applied in tactical planning, such as constraints on maximum clearcut size, or a requirement that all sales or groups of sales must pay for themselves, in proportion to their economic and environmental effects.

In closing, I must conclude there is general agreement that FORPLAN has made a significant contribution to forest planning. The economists, the ecologists, and the managers here have largely been satisfied by the ability of FORPLAN to adequately represent their concerns and address issues at the forest level. Over the last several days I have played the devil's advocate to draw out criticisms of FORPLAN and the criticism is surprisingly mild. Perhaps we are exhausted after 10 years of planning?

Thank you for this opportunity to participate.

[illegible]

Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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